New Horizons: One Year After Pluto Closest approach
What have we learned?

Dennis Reuter
Ralph Instrument Project Scientist
NASA/GSFC, Code 693
dennis.c.reuter@nasa.gov

Credit Belongs to the Entire New Horizons Team

New Horizons

- Completes the Initial Exploration of the Classical Solar System
- Began the exploration of the Third Zone of the Solar System
- Closest Approach to Pluto was on July 14, 2015
  - Fiftieth Anniversary of the First Transmission of Pictures of Mars from a Spacecraft (Mariner 4)
- Results demonstrate once again why it is important to visit unexplored worlds – Pluto is a rockstar (or should I say icestar)

MISSION HISTORY

FIRST CONCEPT: 1989

ALAN STERN AND OTHERS PROPOSE PLUTO MISSION DESIGN
MANY ITERATIONS OF A PLUTO RECON MISSION, UNTIL…

NEW HORIZONS CONCEPT SELECTED: NOV 29, 2001

PI ALAN STERN SWRI BOULDER/ PROJECT MANAGEMENT APL

FIRST MISSION IN "NEW FRONTIERS" CLASS

LAUNCH: JAN 19, 2006

ATLAS V ROCKET FROM CAPE CANAVERAL, FLORIDA

FASTEST VEHICLE LEAVING EARTH'S ENVIRONMENT

JUPITER FLYBY: FEB 28, 2007

GRAVITY ASSIST AND FLYBY REHEARSAL

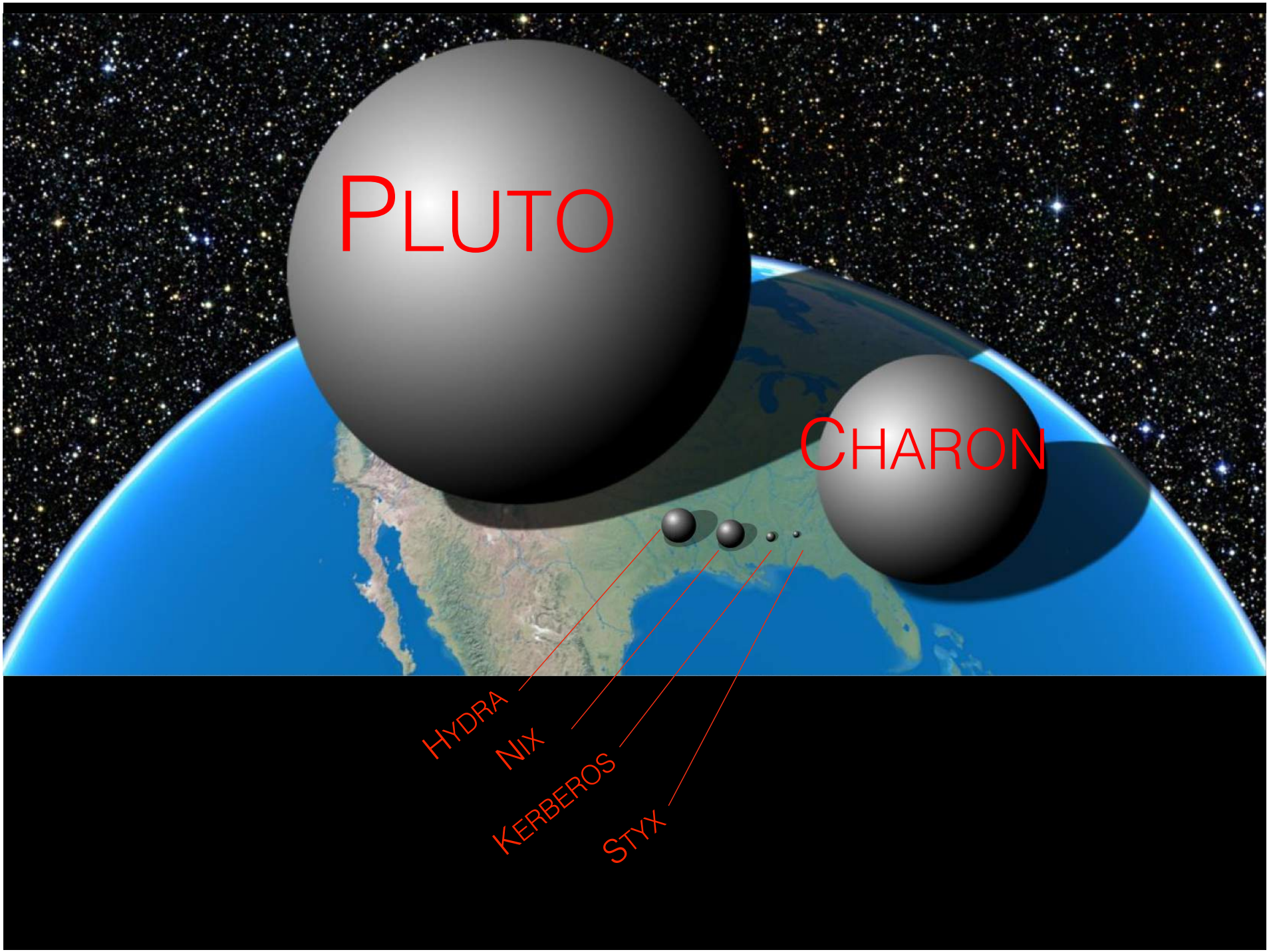
CROSSED NEPTUNE'S ORBIT: AUG 25, 2014

EXACTLY 25 YEARS AFTER VOYAGER 2 VISITED NEPTUNE

PLUTO FLYBY SPANNED JAN-JULY 2015

"BEST EVER" IMAGES STARTED IN MAY 2015

DATA DOWNLINKED THROUGH LATE 2016


PLUTO
CHARON
HYDRA
NIX
KERBEROS
STYX

MISSION OBJECTIVES

PRIMARY OBJECTIVES:

- CHARACTERIZE GLOBAL GEOLOGY AND MORPHOLOGY OF PLUTO AND CHARON
- MAP SURFACE COMPOSITION OF PLUTO AND CHARON
- CHARACTERIZE THE NEUTRAL ATMOSPHERE OF PLUTO AND ITS ESCAPE RATE

SECONDARY OBJECTIVES:

- CHARACTERIZE TIME VARIABILITY OF PLUTO'S SURFACE AND ATMOSPHERE
- IMAGE PLUTO AND CHARON IN STEREO
- MAP TERMINATORS OF PLUTO & CHARON AT HIGH RES
- MAP COMPOSITION OF SELECTED AREAS OF PLUTO AND CHARON AT HIGH RES
- CHARACTERIZE PLUTO'S IONOSPHERE AND SOLAR WIND INTERACTION
- SEARCH FOR NEUTRAL SPECIES, HYDROCARBONS, AND NITRILES IN PLUTO'S UPPER ATMOSPHERE
- SEARCH FOR ATMOSPHERE AROUND CHARON
- DETERMINE BOND ALBEDOS FOR PLUTO AND CHARON
- MAP SURFACE TEMPERATURES OF PLUTO AND CHARON

TERTIARY OBJECTIVES:

- CHARACTERIZE ENERGETIC PARTICLE ENVIRONMENT OF PLUTO AND CHARON
- REFINE BULK PARAMETERS (RADII, MASSES, DENSITIES) AND ORBITS OF PLUTO AND CHARON
- SEARCH FOR MAGNETIC FIELDS OF PLUTO AND CHARON
- SEARCH FOR ADDITIONAL MOONS AND RINGS

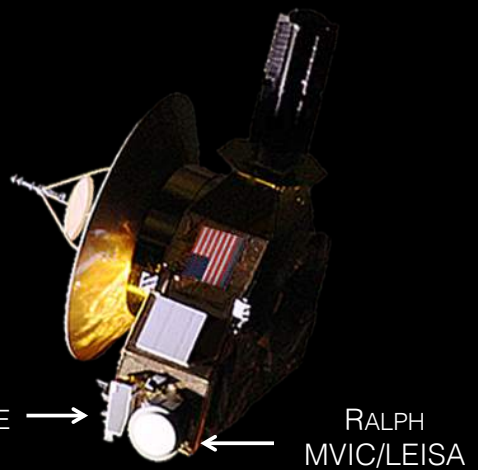
THE SPACECRAFT

OBJECTIVE:
FIRST EXPLORATION OF THE PLUTO SYSTEM

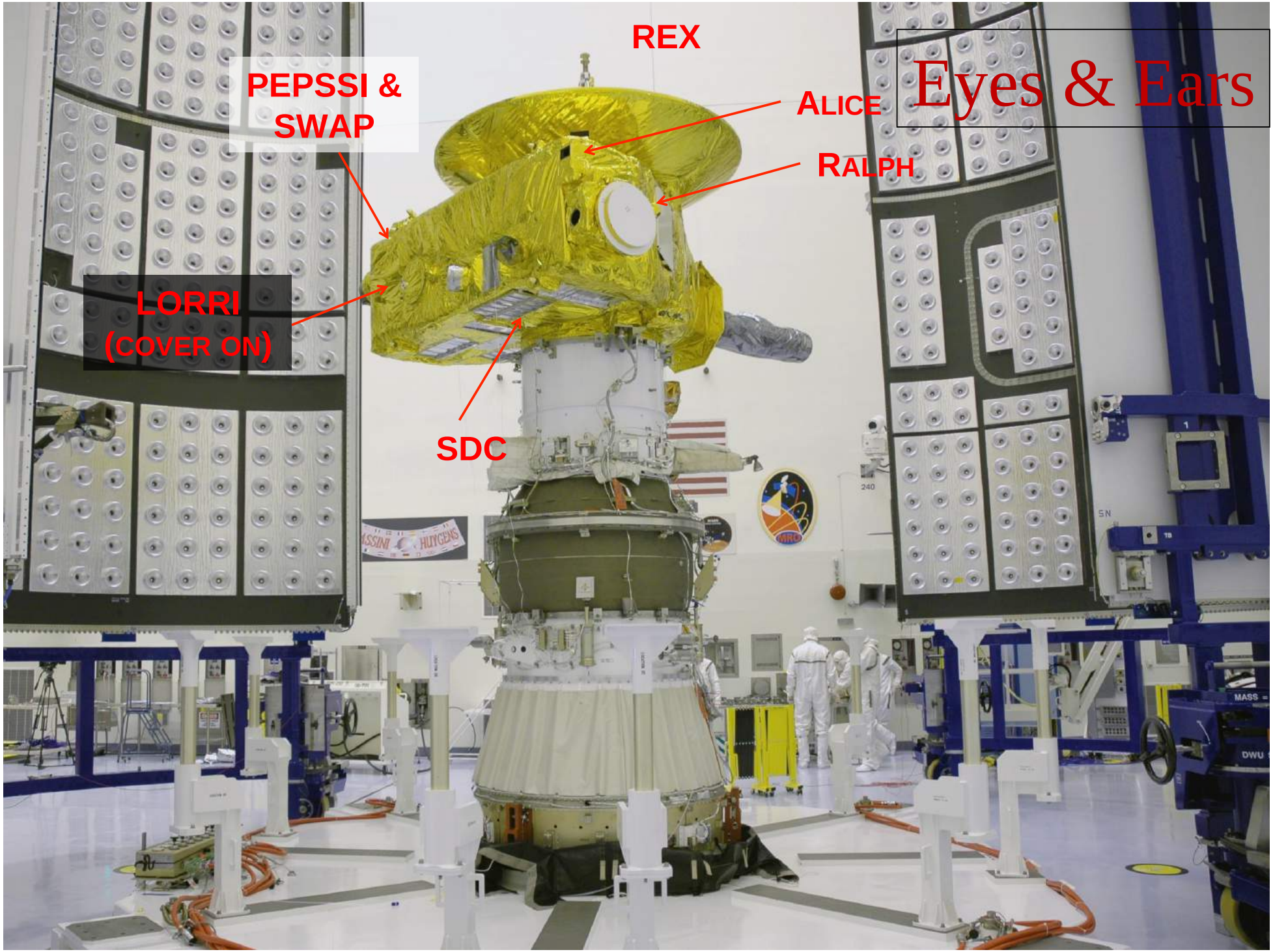
LAUNCHED:
JANUARY 19 2006, ATLAS V-551 ROCKET

POWER SUPPLY:
RTG WITH 11KG PU-238, 202 WATTS AT PLUTO

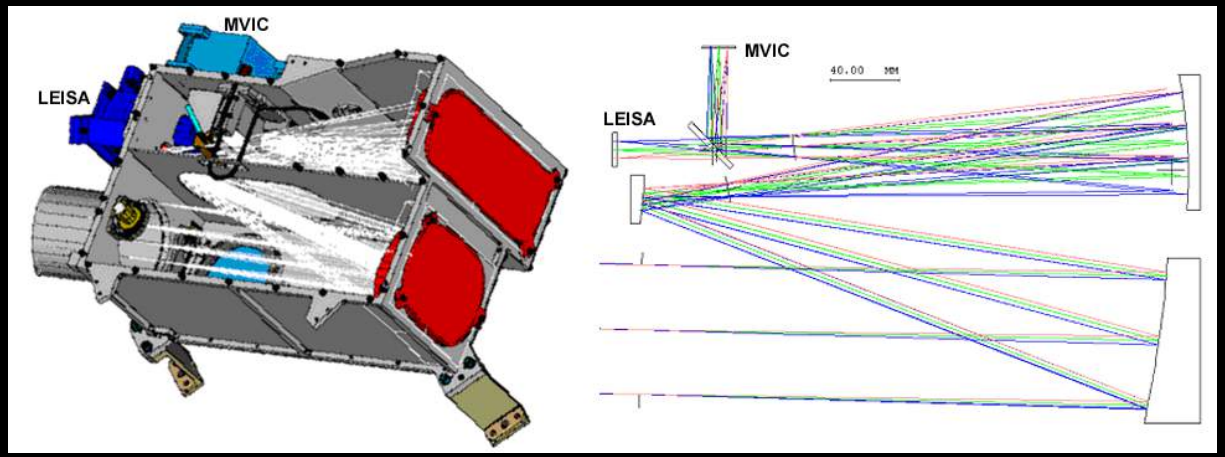
COMMUNICATIONS:
2.1 METER HIGH-GAIN ANTENNA
X-BAND UPLINK/DOWNLINK, 3000 BPS MAX AT PLUTO
USES 30W OF POWER

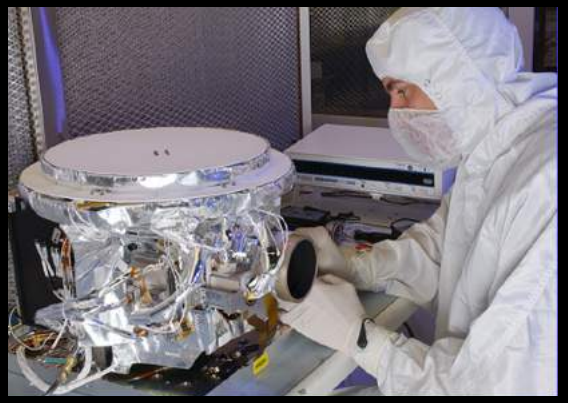


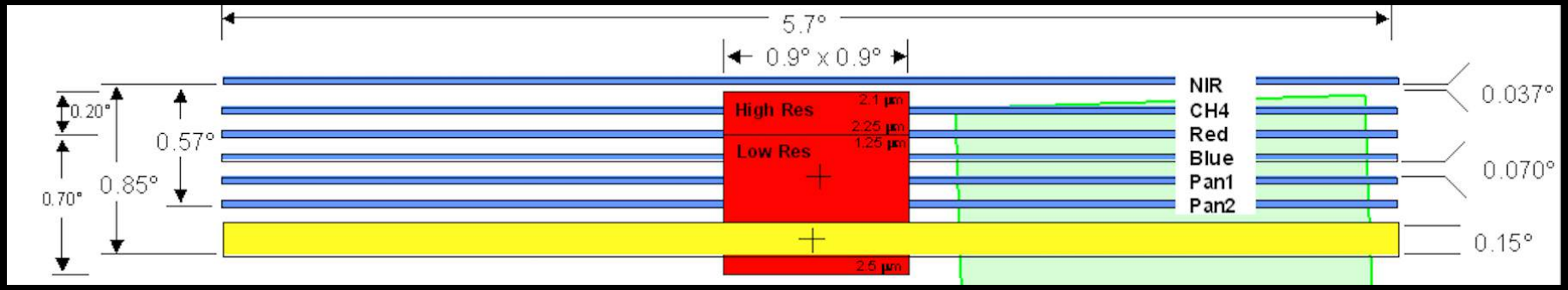
SCIENCE INSTRUMENTS PROVIDE COMPLEMENTARY DATA:
LORRI - HIGH RESOLUTION PANCHROMATIC CAMERA
MVIC - COLOR AND PANCHROMATIC CAMERA
LEISA - NIR SPECTRAL MAPPER
ALICE - UV SPECTRAL MAPPER
SWAP AND *PEPSSI* - PLASMA ENVIRONMENT INSTRUMENTS
REX - RADIO SCIENCE EXPERIMENT
VENETIA BURNEY STUDENT DUST COUNTER


REX
PEPSSI &
SWAP
ALICE
RALPH
LORRI
(COVER ON)
SDC
Eyes & Ears

Ralph: IR and Visible Camera in One Box



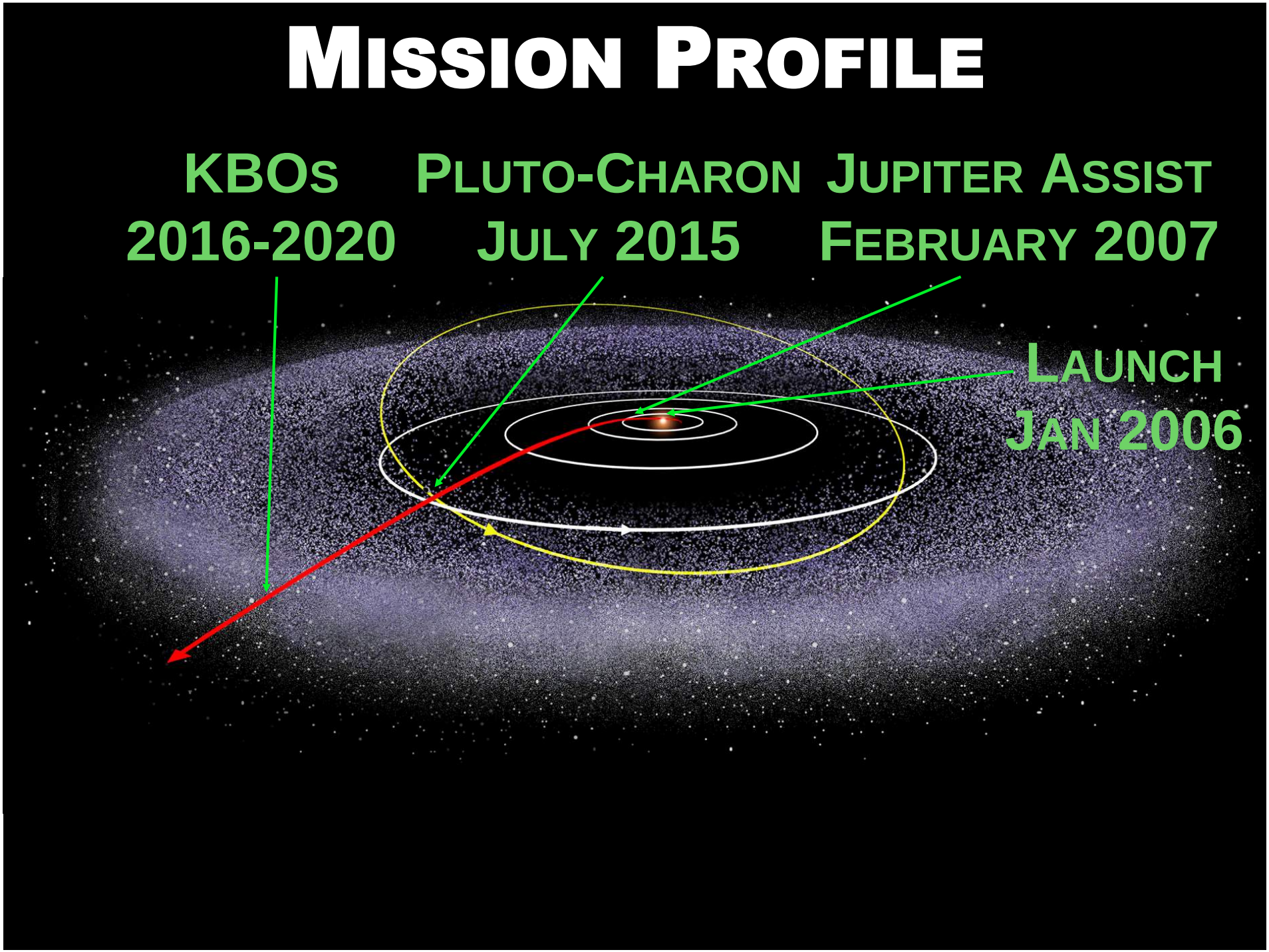




Ralph Provides Composition Information

- Ralph/MVIC
  - Panchromatic Band
  - 4 visible/NIR colors including a methane band filter
- Ralph/LEISA
    - 1.25 – 2.5 μm, $\lambda/\Delta\lambda$ = 240
    - 2.1 – 2.25 μm, $\lambda/\Delta\lambda$ = 560
      - N_2 feature at 2.15 μm useful for temperature

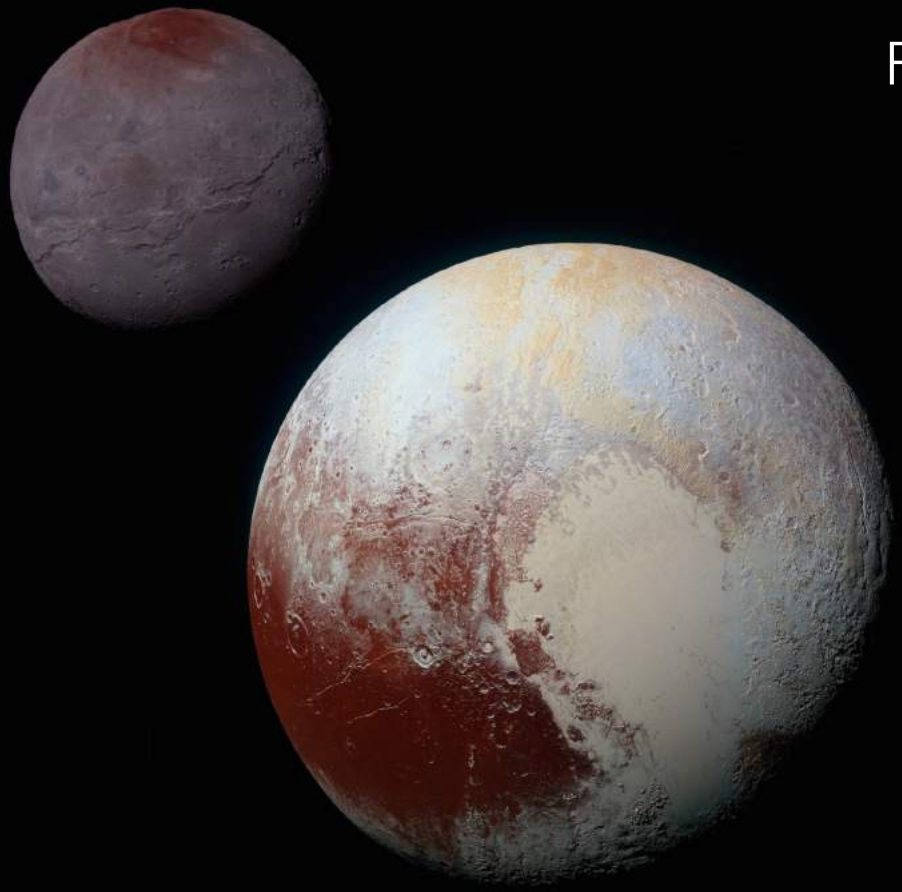
Mission Profile



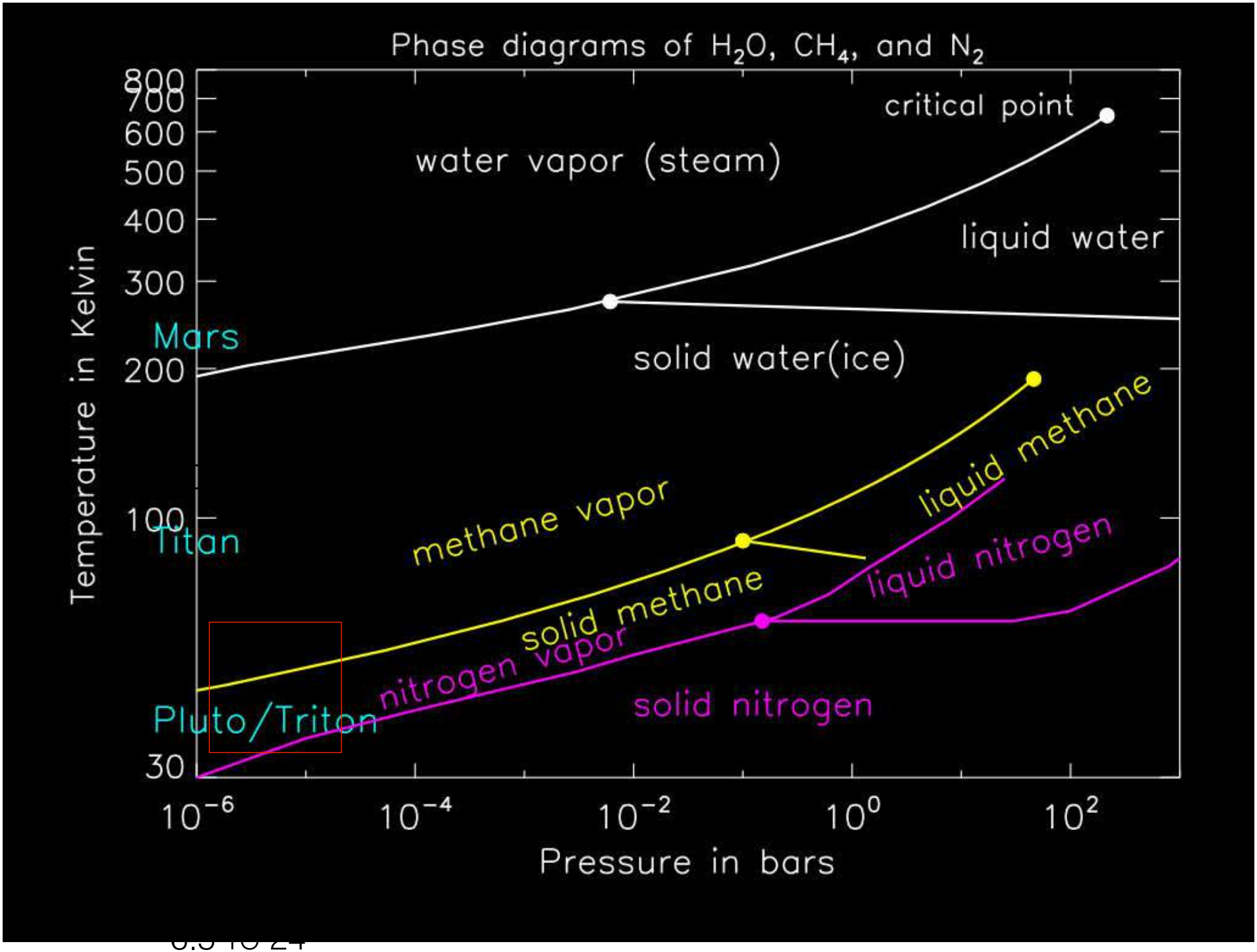
Our Best View of Pluto Prior to New Horizons was only a few pixels across (from Hubble)

New Horizons has radically changed our view

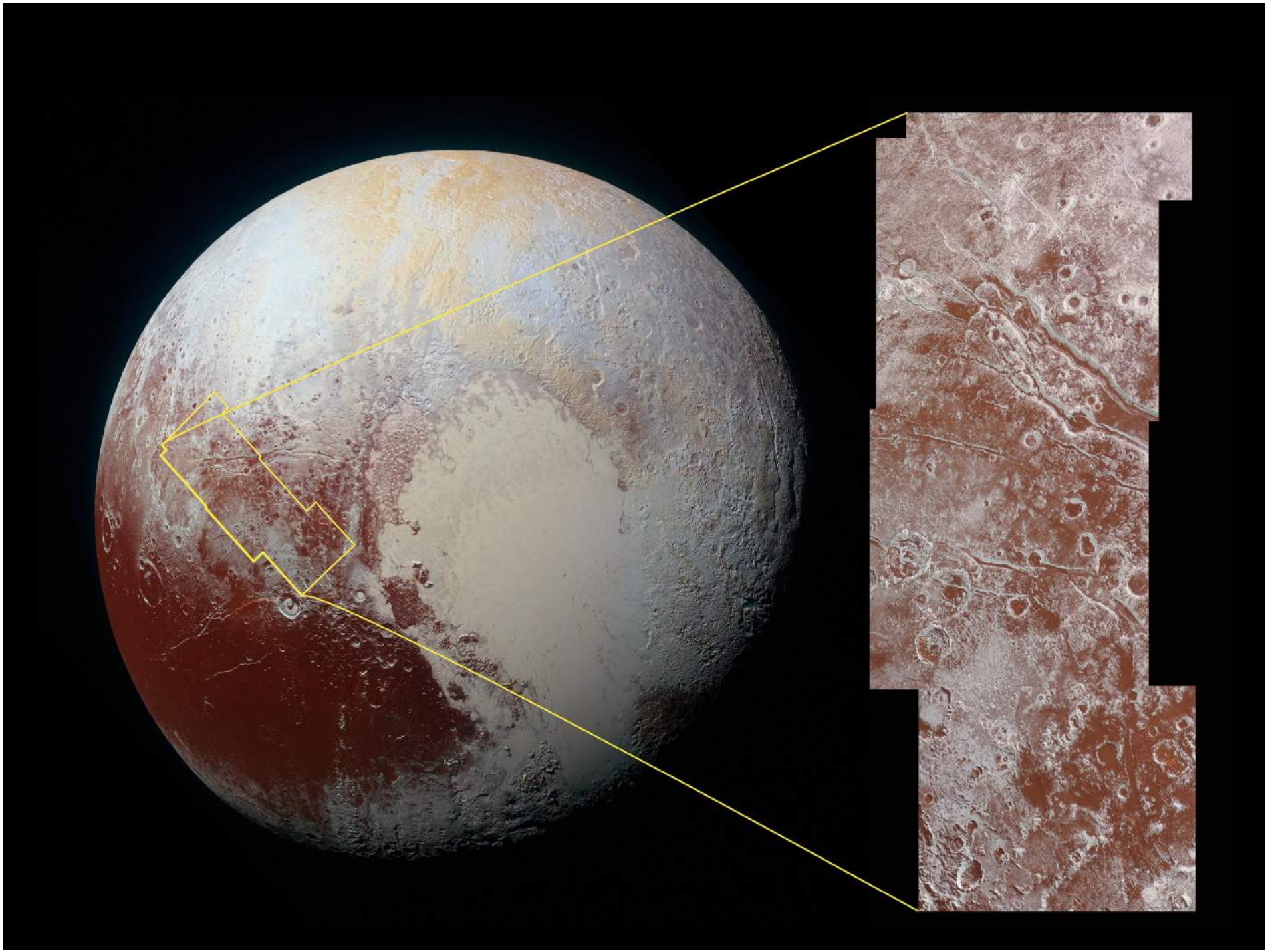
Pluto and Charon in Color

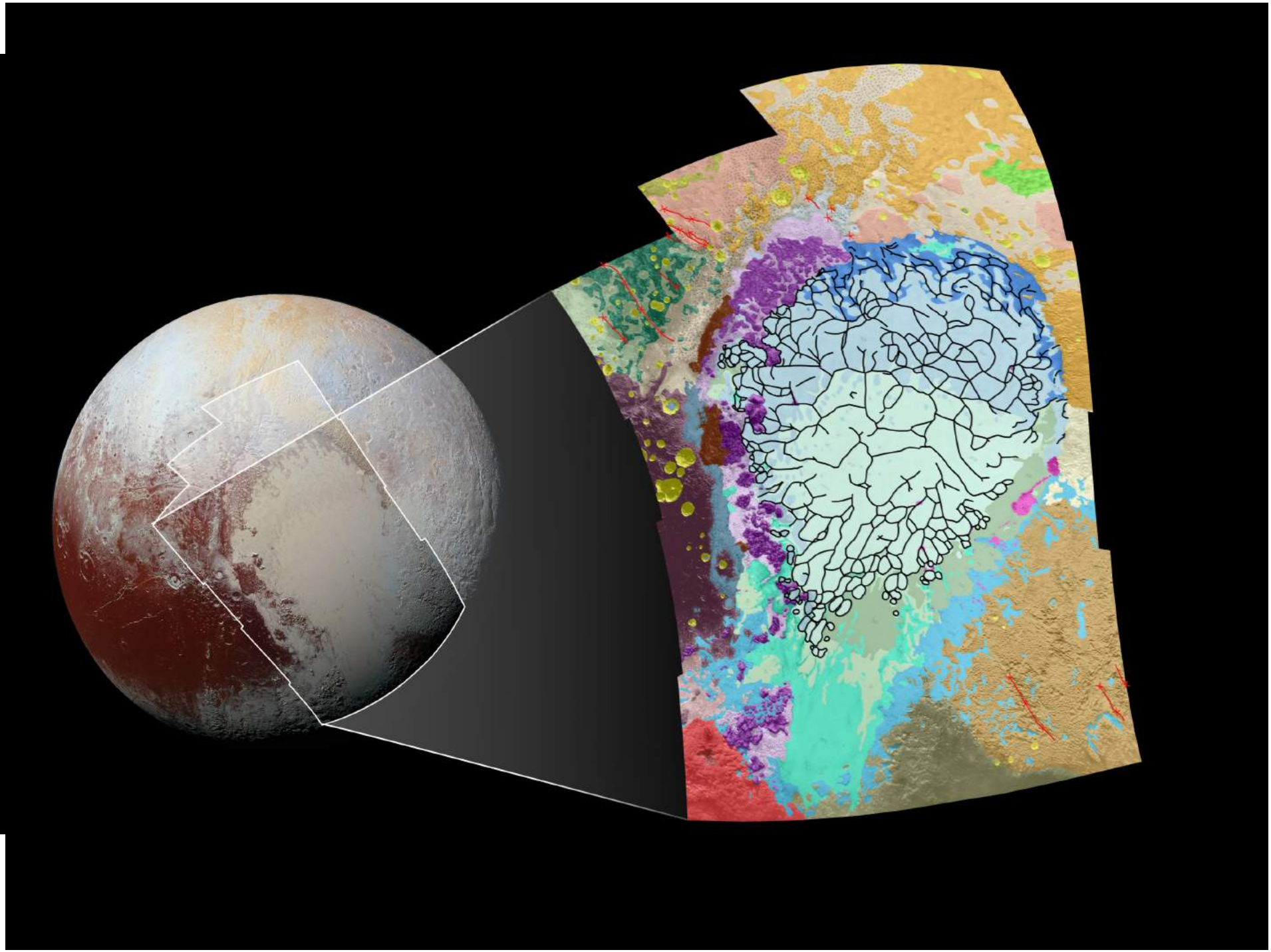


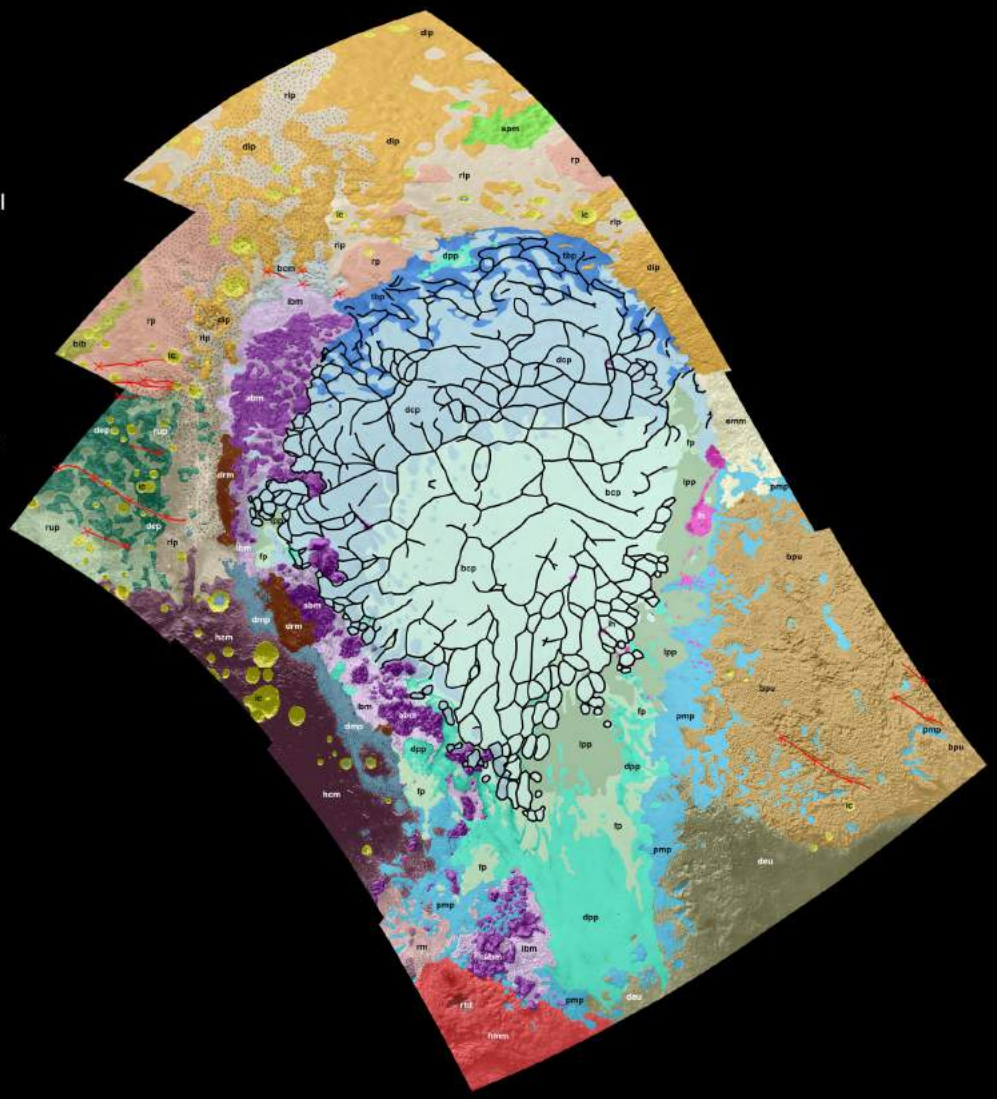
Note: In the following charts, all Pluto system surface feature names are informal.

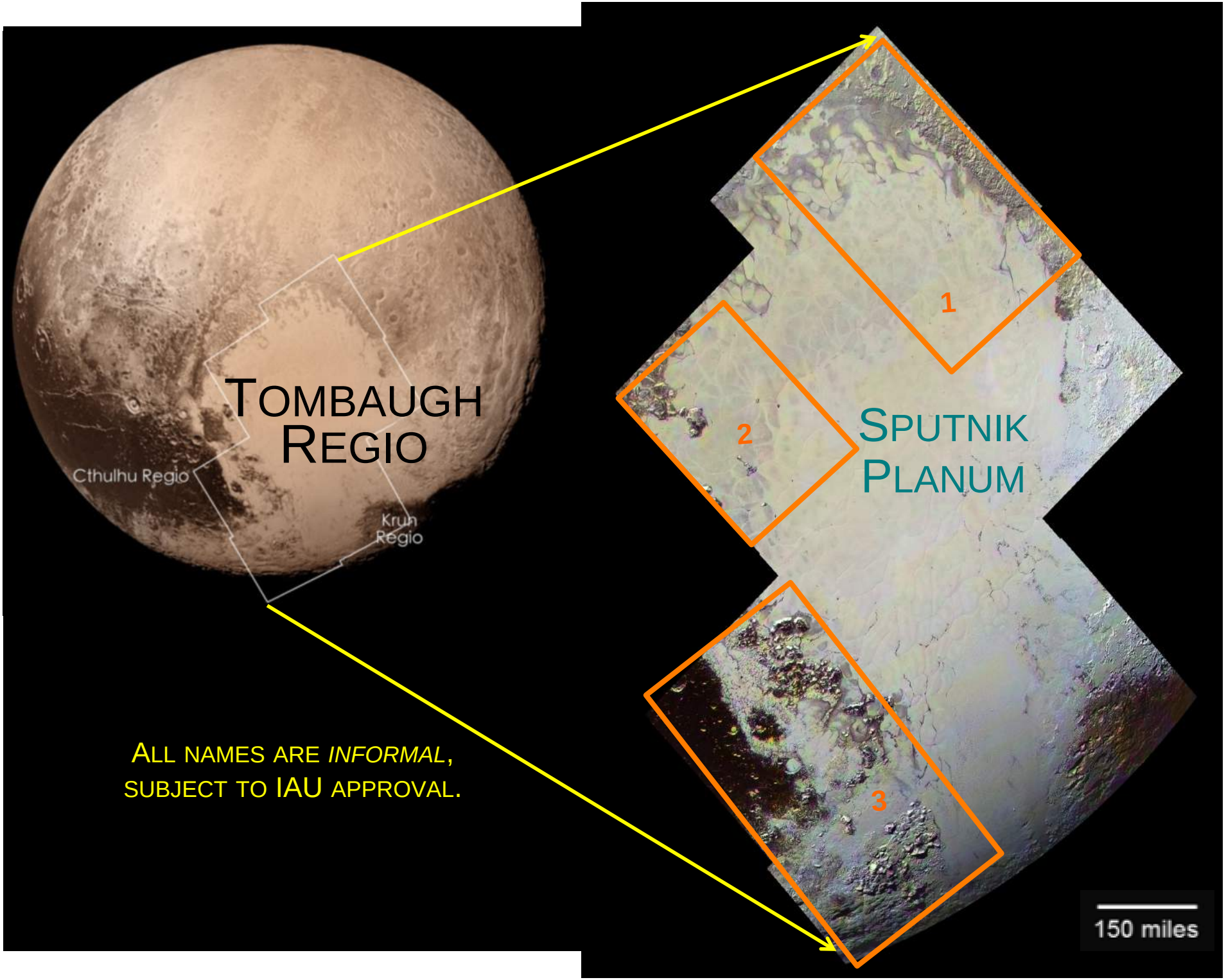

Phase diagrams of H_2O, CH_4, and N_2
800
700
600
500
400
300
200
100
30
Temperature in Kelvin
critical point
water vapor (steam)
liquid water
Mars
solid water(ice)
methane vapor
liquid methane
Titan
liquid nitrogen
solid methane
nitrogen vapor
Pluto/Triton
solid nitrogen
10^{-6}
10^{-4}
10^{-2}
10^{0}
10^{2}
Pressure in bars

UBARS



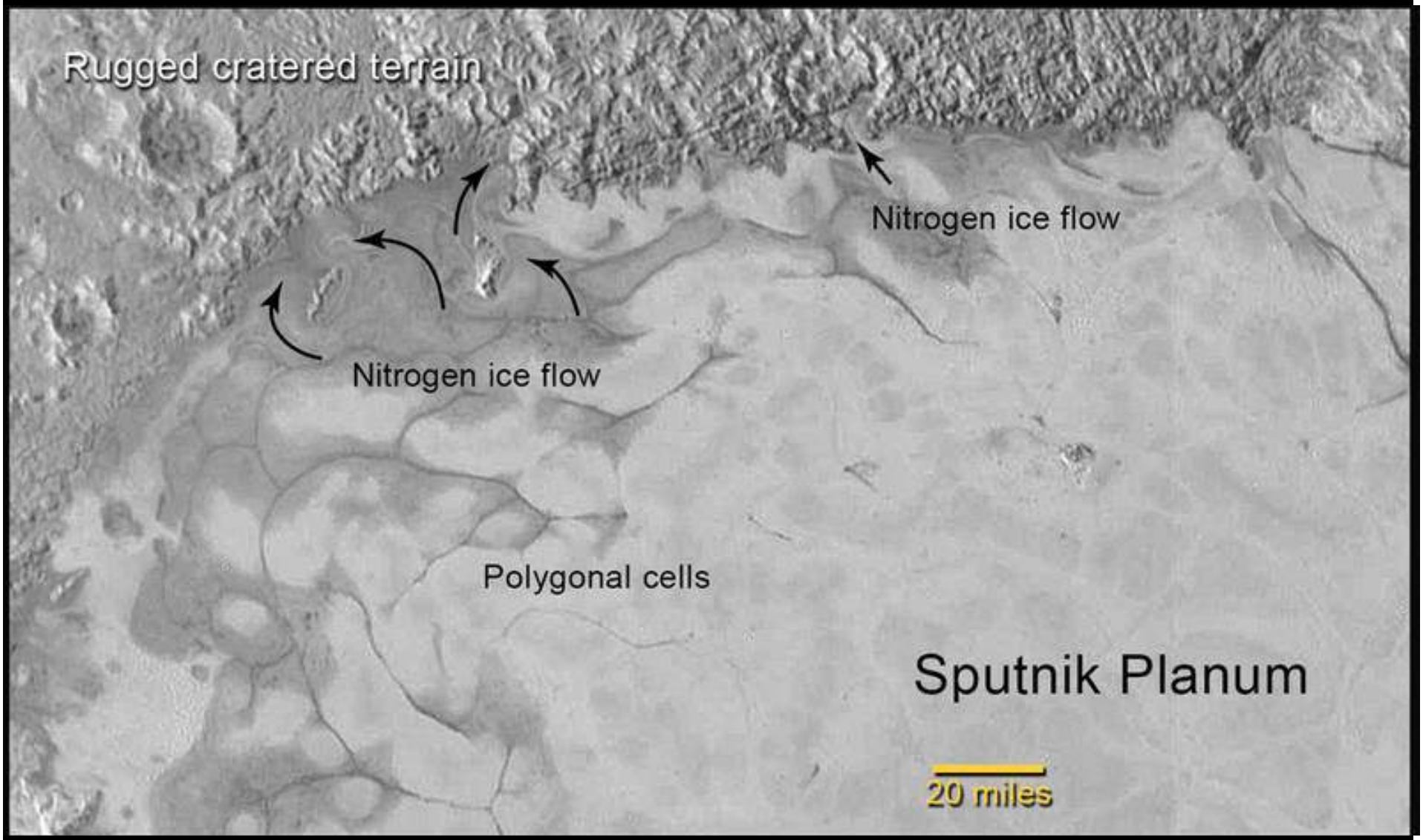



hmm Hummocky mound material
rtd Radially-textured depression
rm Rubbly material
hcm Rugged, heavily cratered material
drm Dark, ridged material
rp Rough plateau
dip Dissected plateau
spm Deep, steep-sided pitted material
dep Degraded plateau
bcm Bright chaotic material
rlp Rough lowland plains
rup Rough upland plains
emm Eroded mantle material
bpu Bright pitted uplands
deu Dark eroded uplands
Washboard texture
bcp Bright, cellular plains
dcp Dark, cellular plains
tbp Dark, trough-bounding plains
fp Featureless plains
dpp Deeply pitted plains
lpp Lightly pitted plains
pmp Patchy, pitted marginal plains
dmp Dark, pitted marginal plains
abm Chaotic, angular, blocky mountains
ibm Chaotic, inter-block material
ih Isolated hills
ic Well-preserved impact crater
bib Impact basin material
Trough in cellular terrain
Extensional faultline

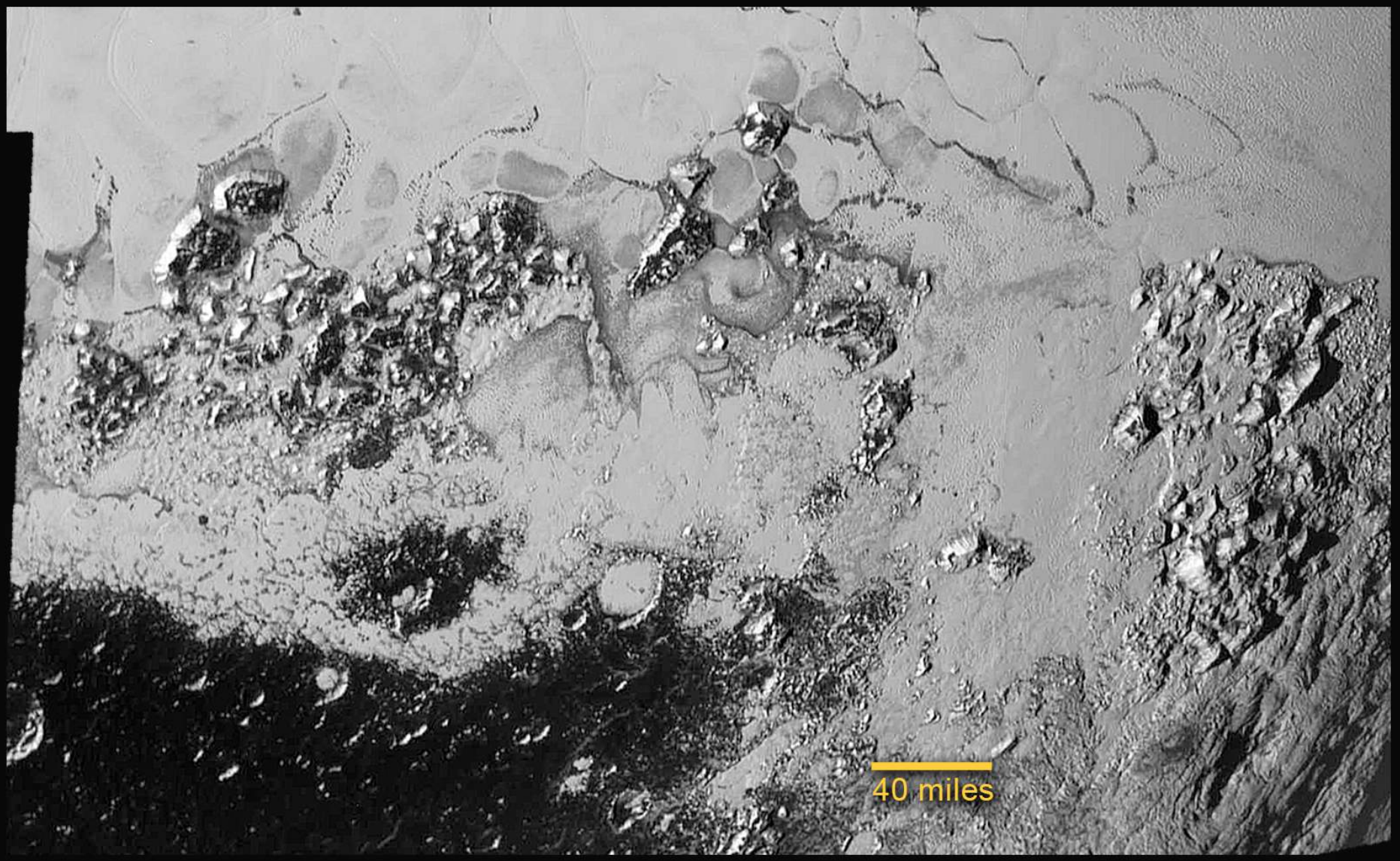


ALL NAMES ARE *INFORMAL*, SUBJECT TO IAU APPROVAL.

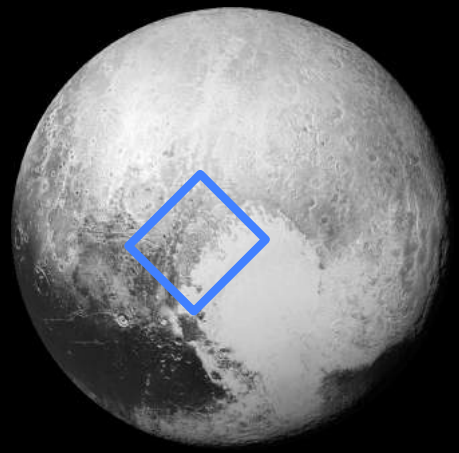
1) Nitrogen Ice Glacial Flows

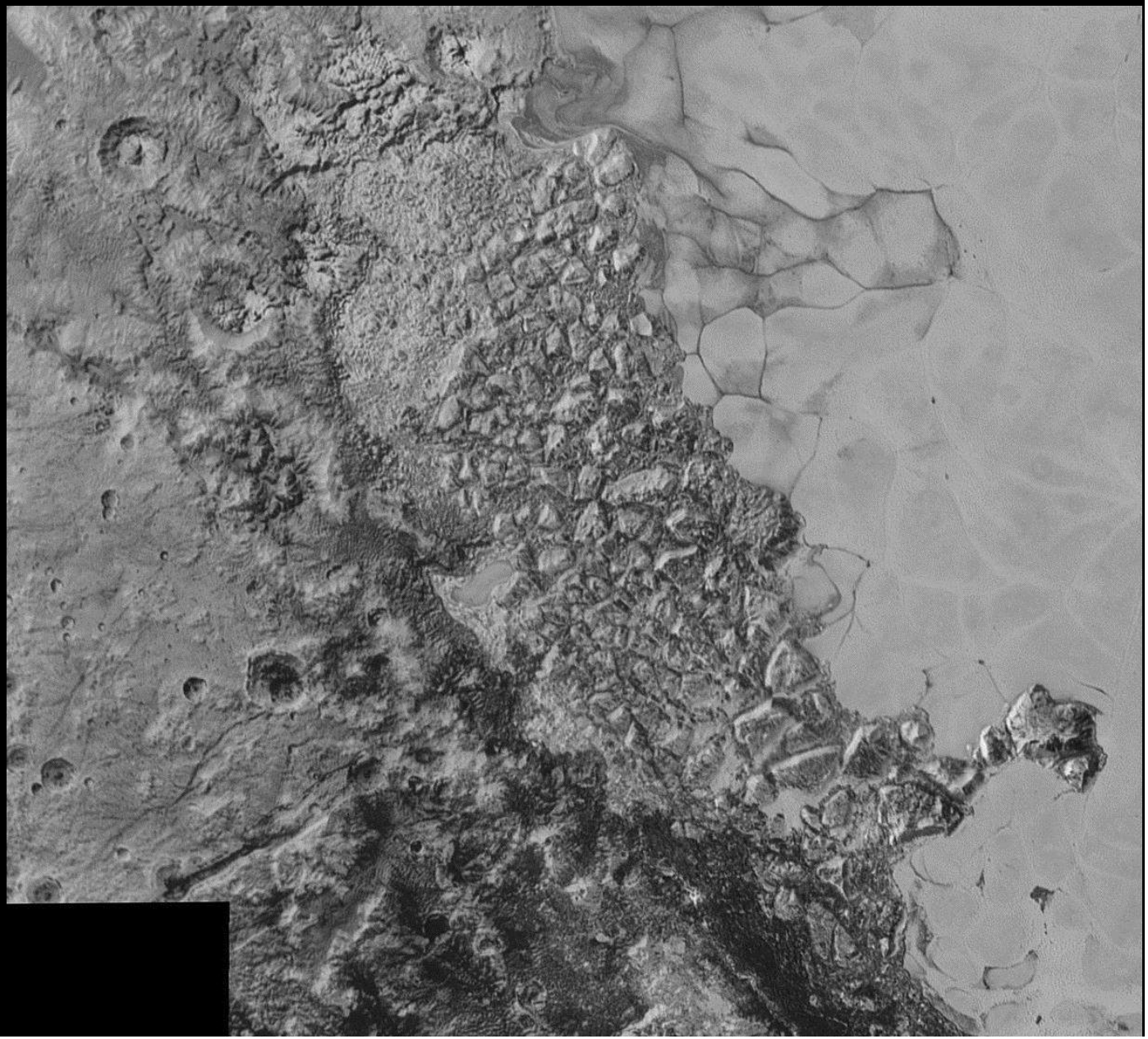


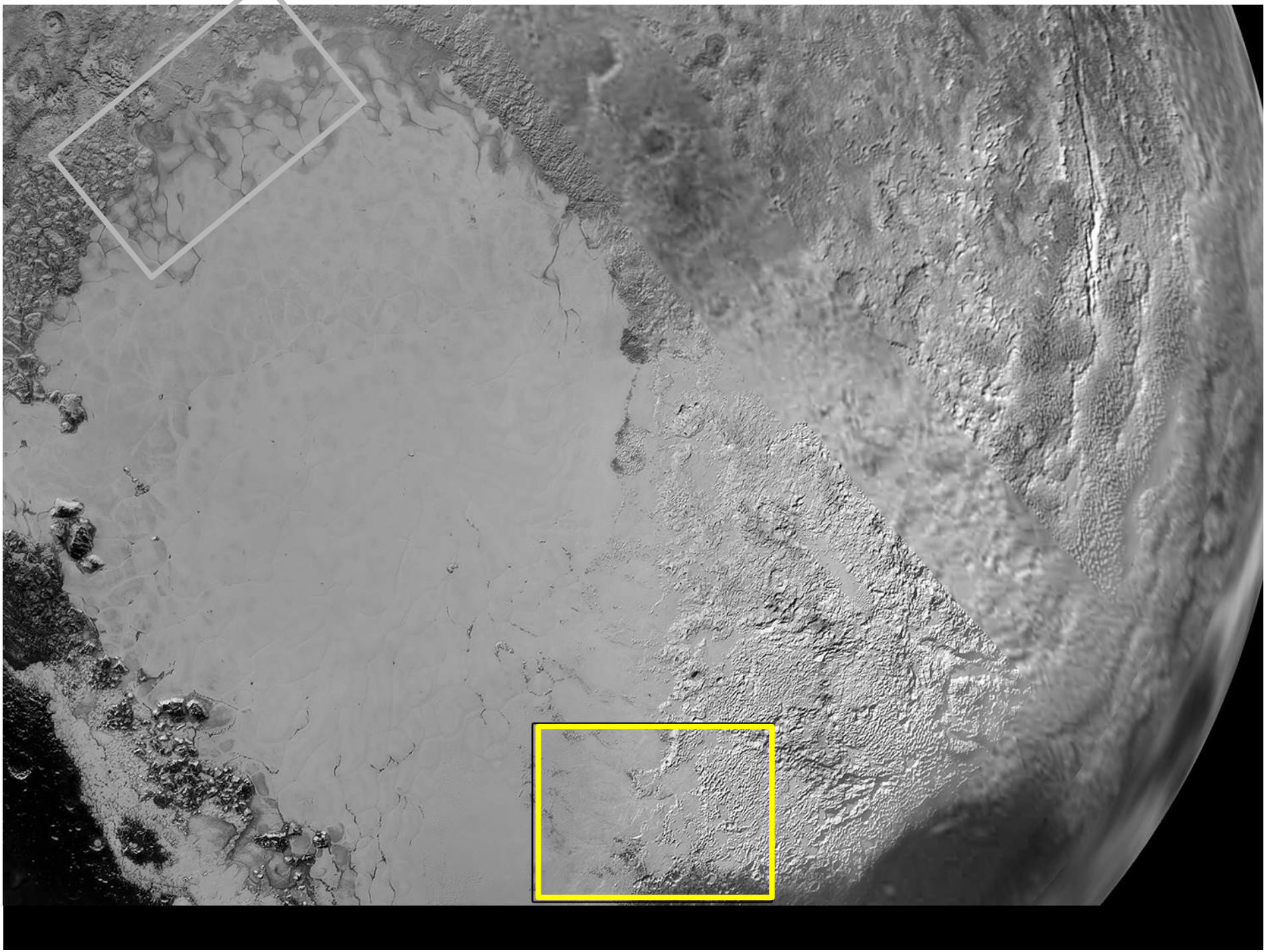
3) Boundary Between Glacial Flow and Older Surface

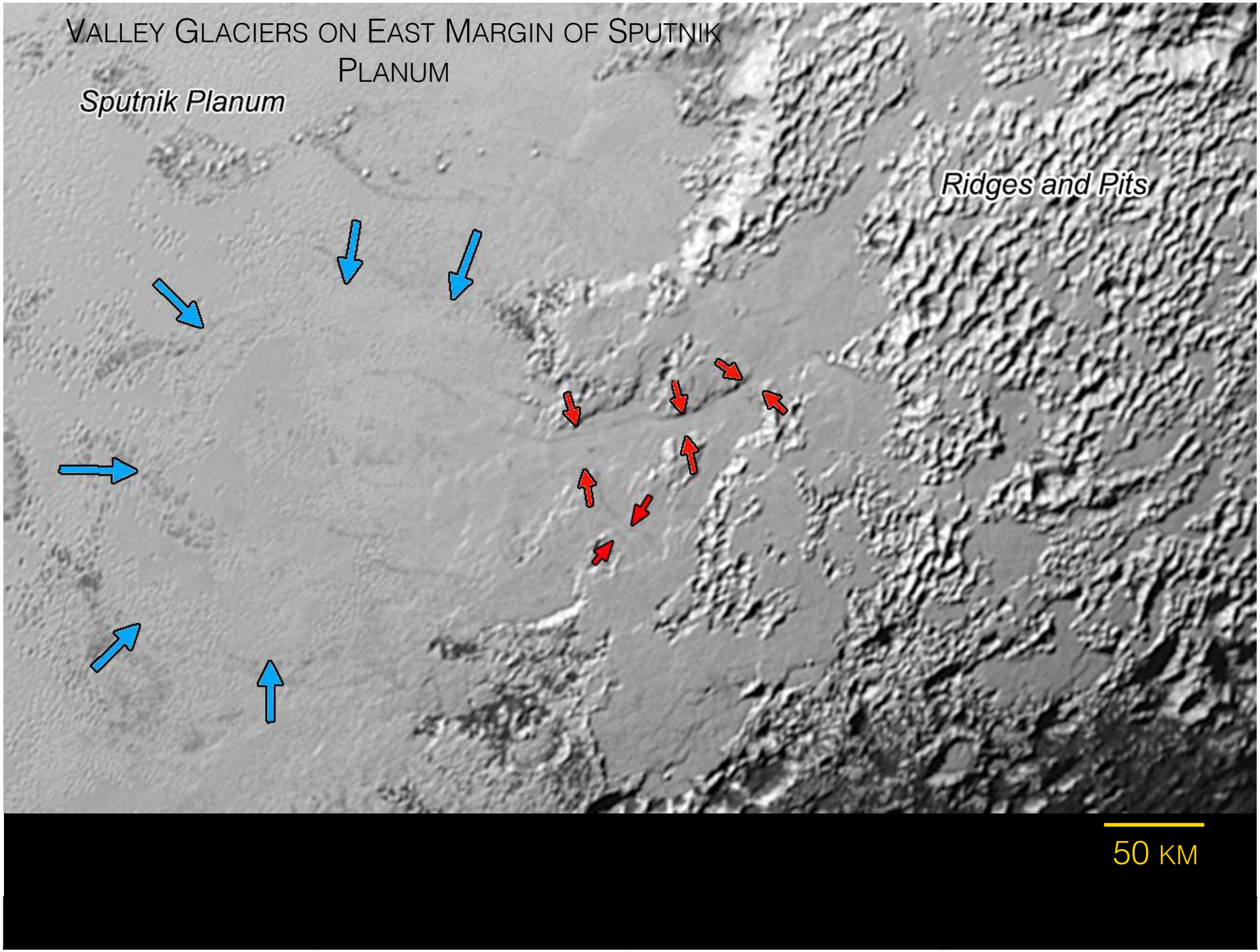


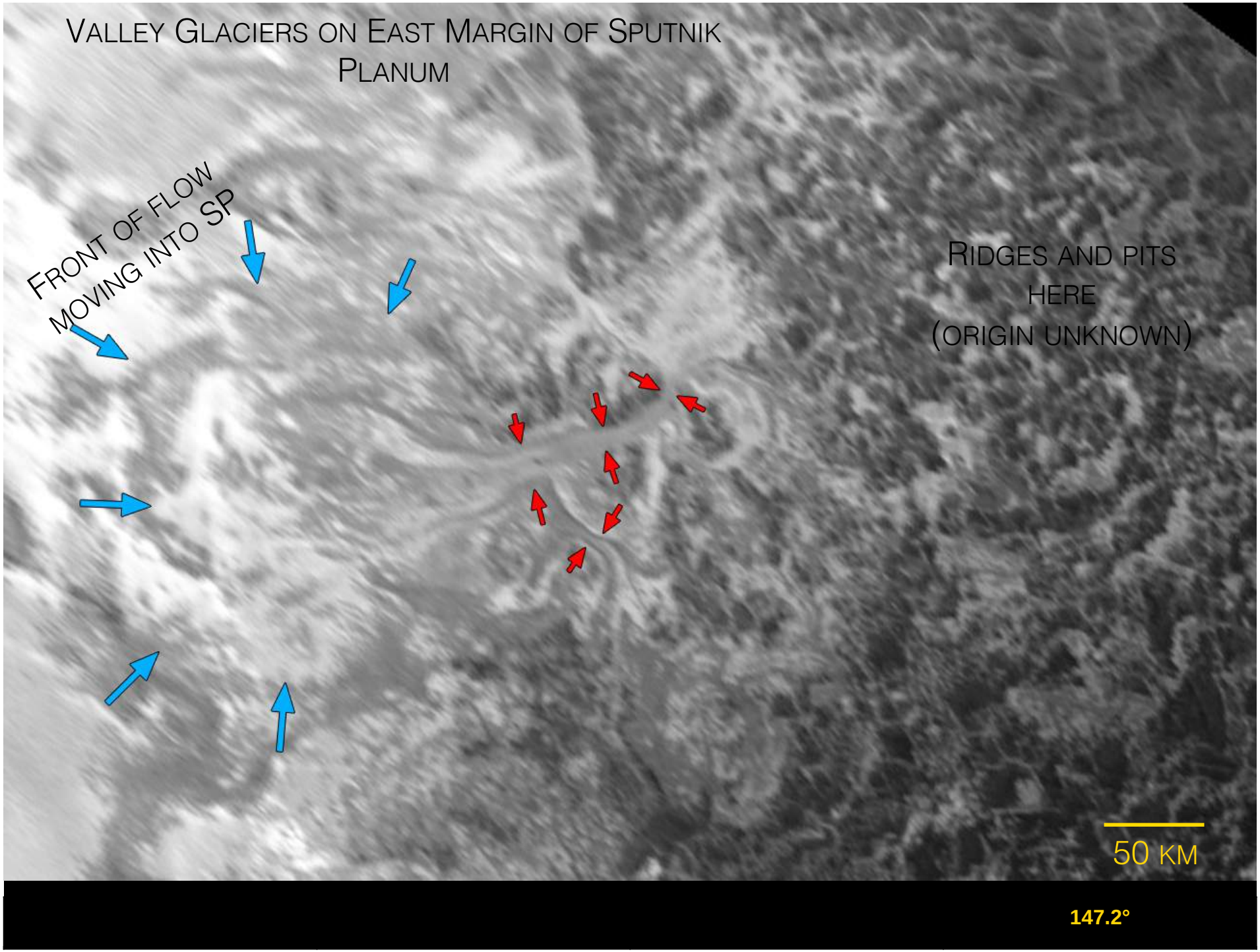
Region showing mountains of water-ice

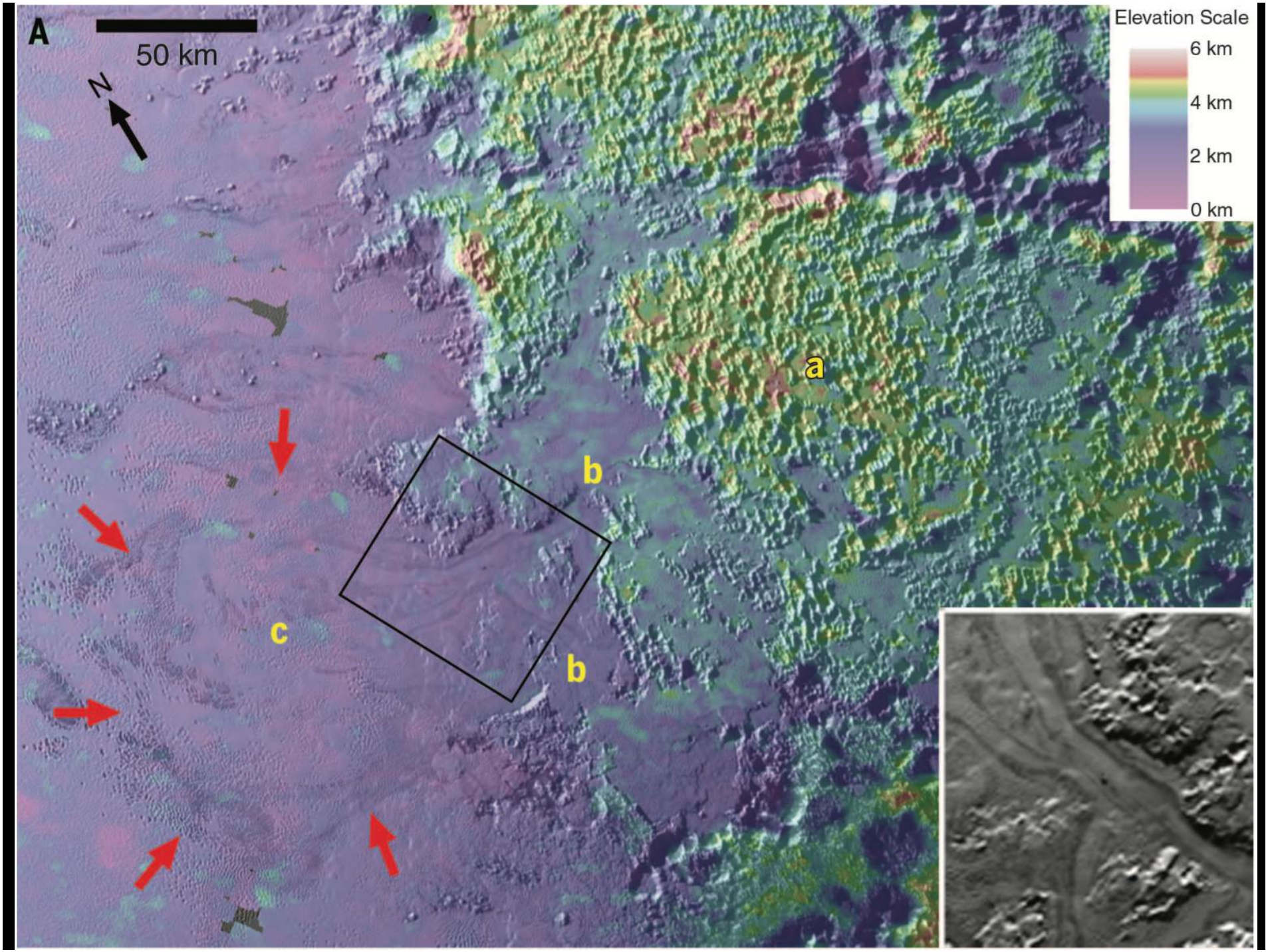







VALLEY GLACIERS ON EAST MARGIN OF SPUTNIK PLANUM
Sputnik Planum
Ridges and Pits
50 KM


VALLEY GLACIERS ON EAST MARGIN OF SPUTNIK PLANUM
FRONT OF FLOW MOVING INTO SP
RIDGES AND PITS HERE (ORIGIN UNKNOWN)
50 KM
147.2°


A
50 km
N
Elevation Scale
6 km
4 km
2 km
0 km
a
b
b
c

POLYGONAL CELLS

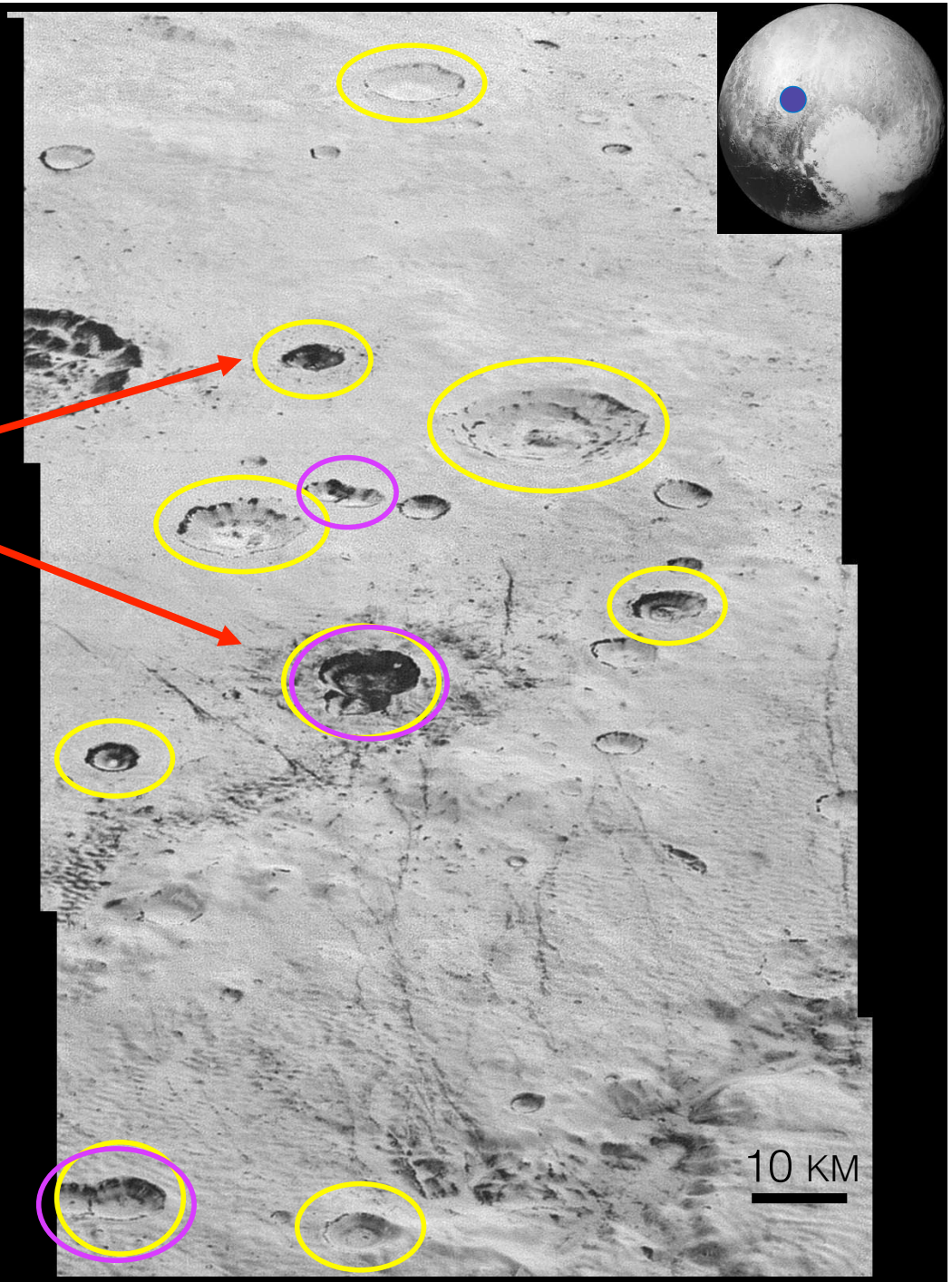
LIKELY SIGNATURES OF TOPOGRAPHIC UPLIFT DUE TO SOLID STATE CONVECTION OF WEAK VOLATILE ICES LIKE N_2 AND CO.

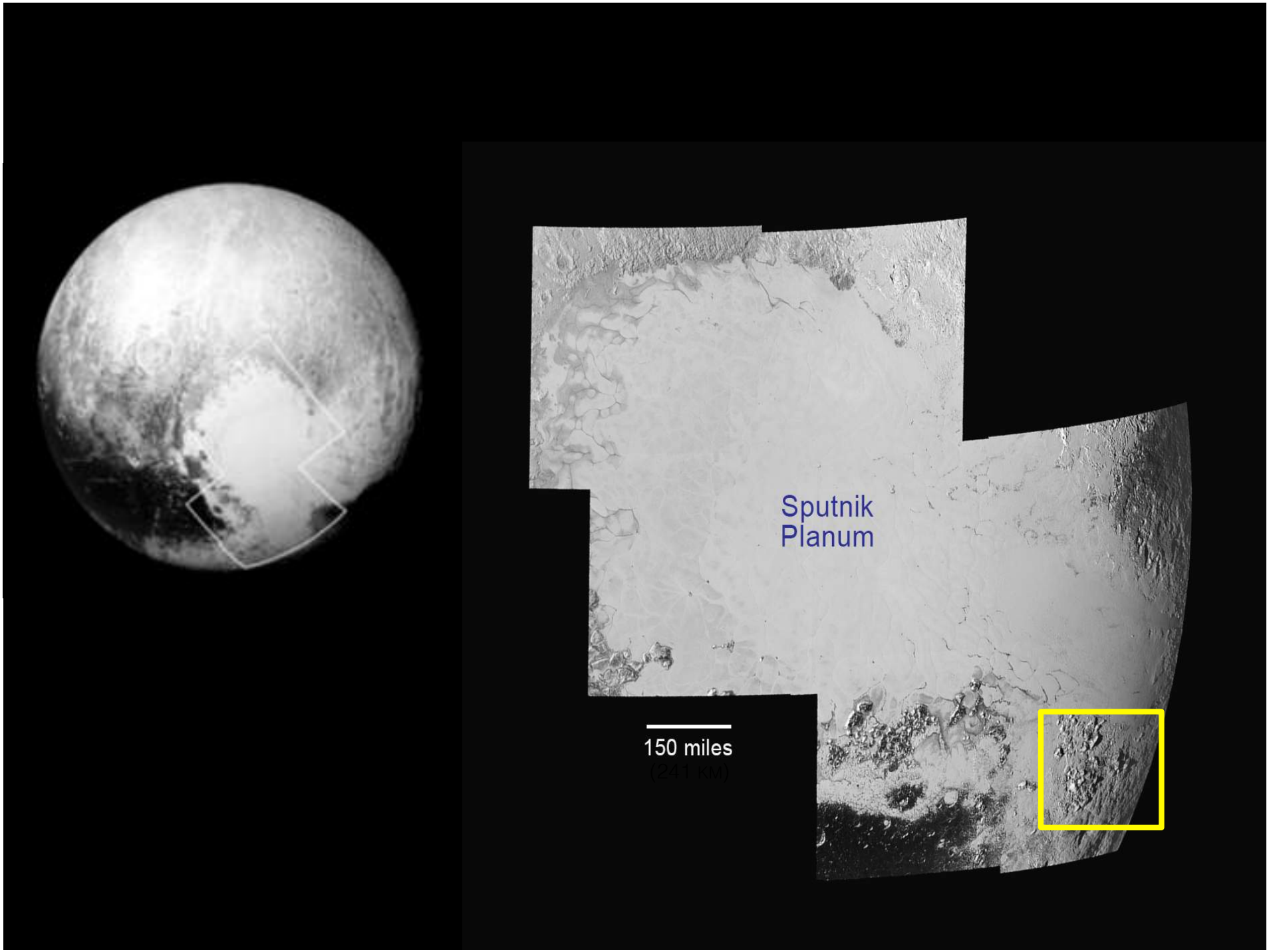
SEE MCKINNON ET AL. NATURE JUNE 2

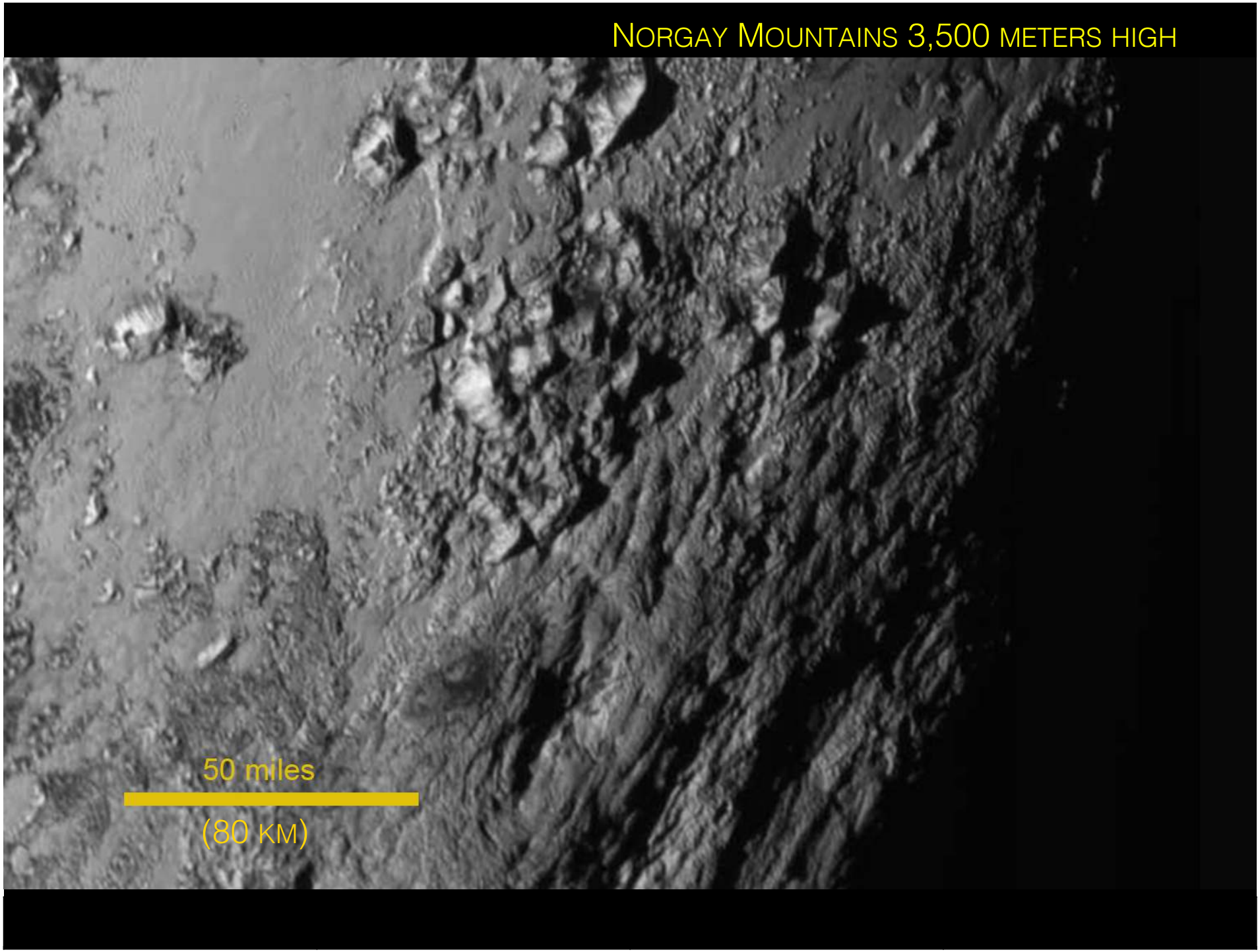
Pluto – Highest Res

80 m px^{-1}

- Ejecta Blankets
  - No obvious secondary craters
  - Nested craters (subsurface layering)
  - Youngest craters are darkest
- Doublets?



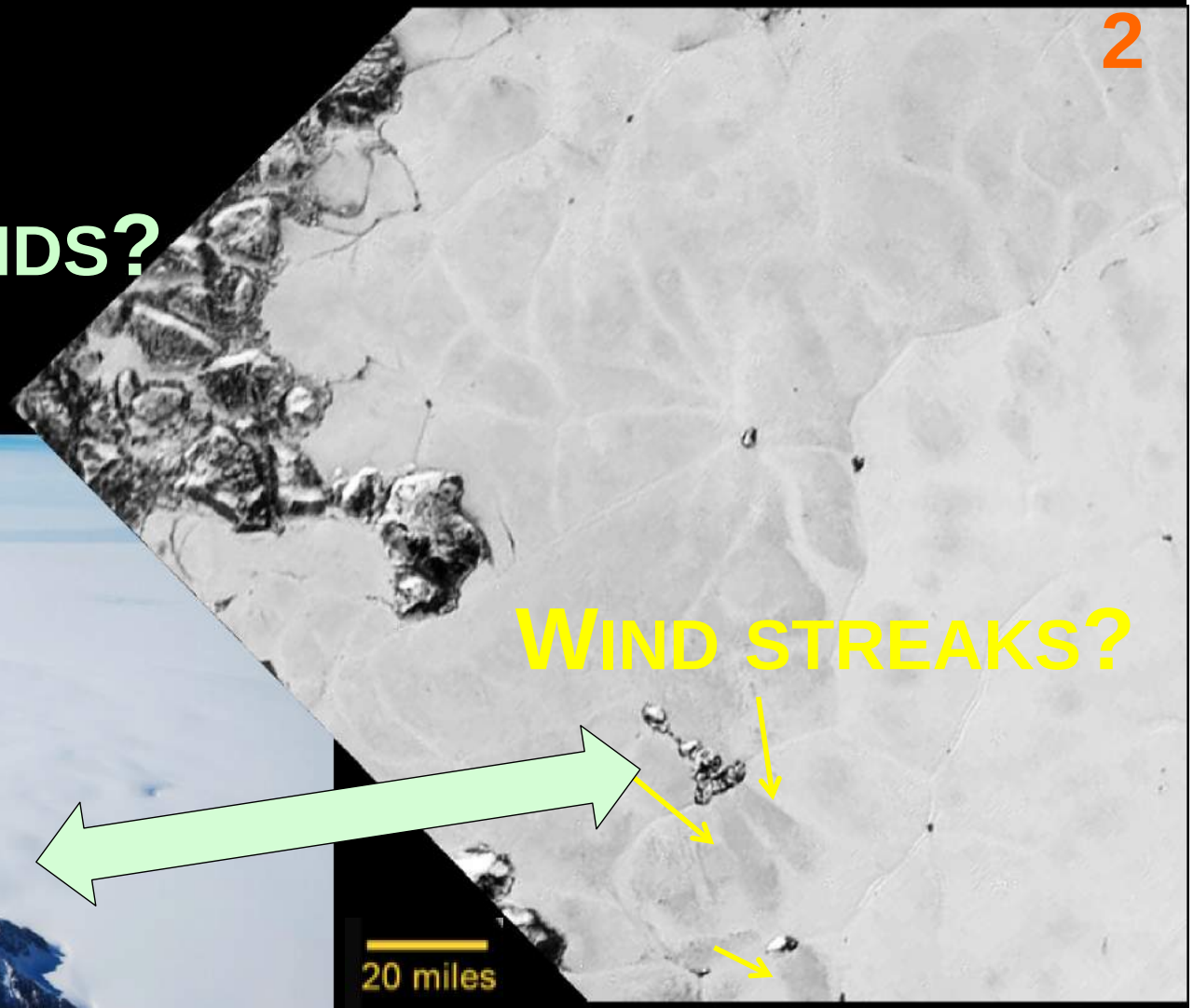

Sputnik
Planum
150 miles
(241 KM)


NORGAY MOUNTAINS 3,500 METERS HIGH
50 miles
(80 KM)

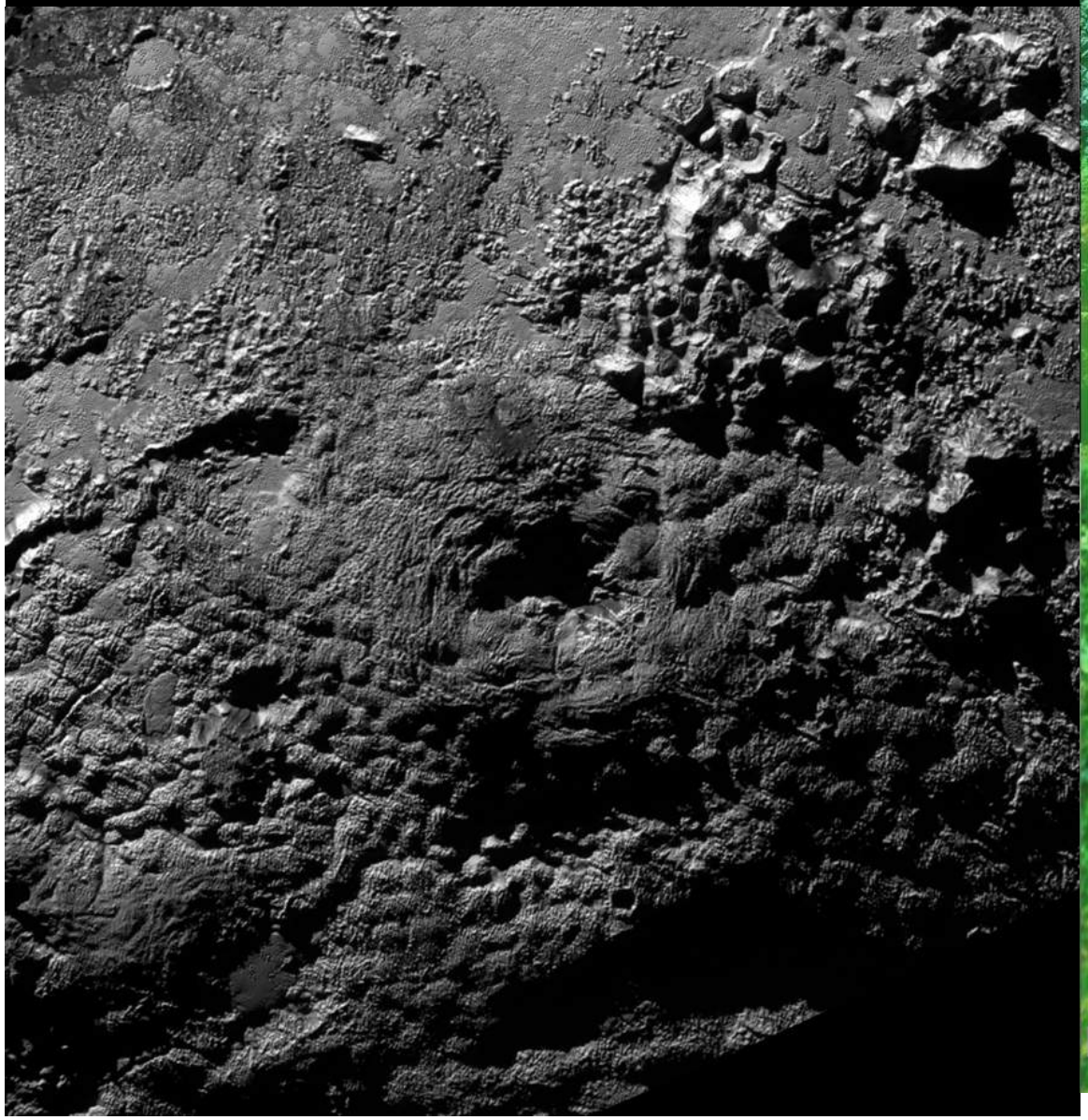
MVIC Color images show surface composition variety

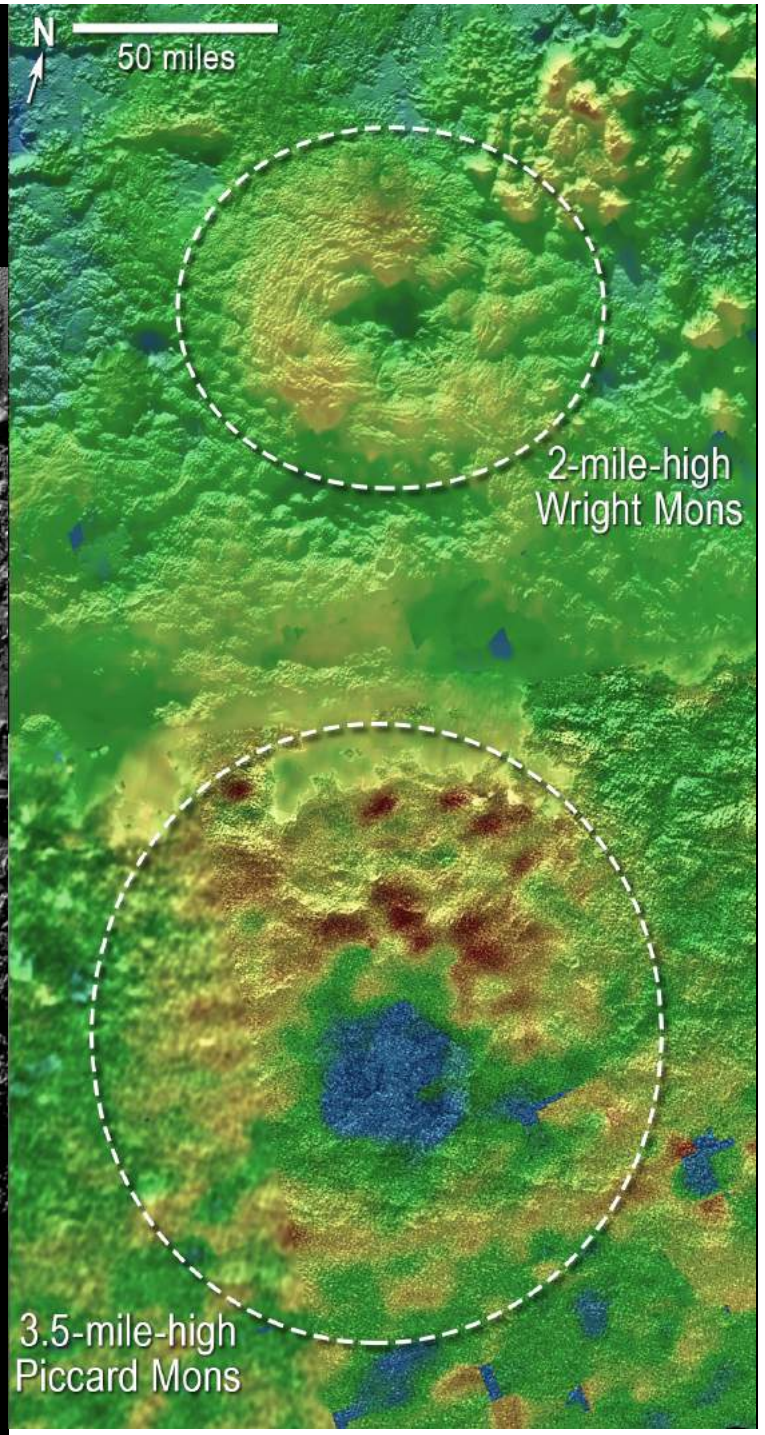
GLACIAL ISLANDS?

NUNATEK IN ANTARCTICA

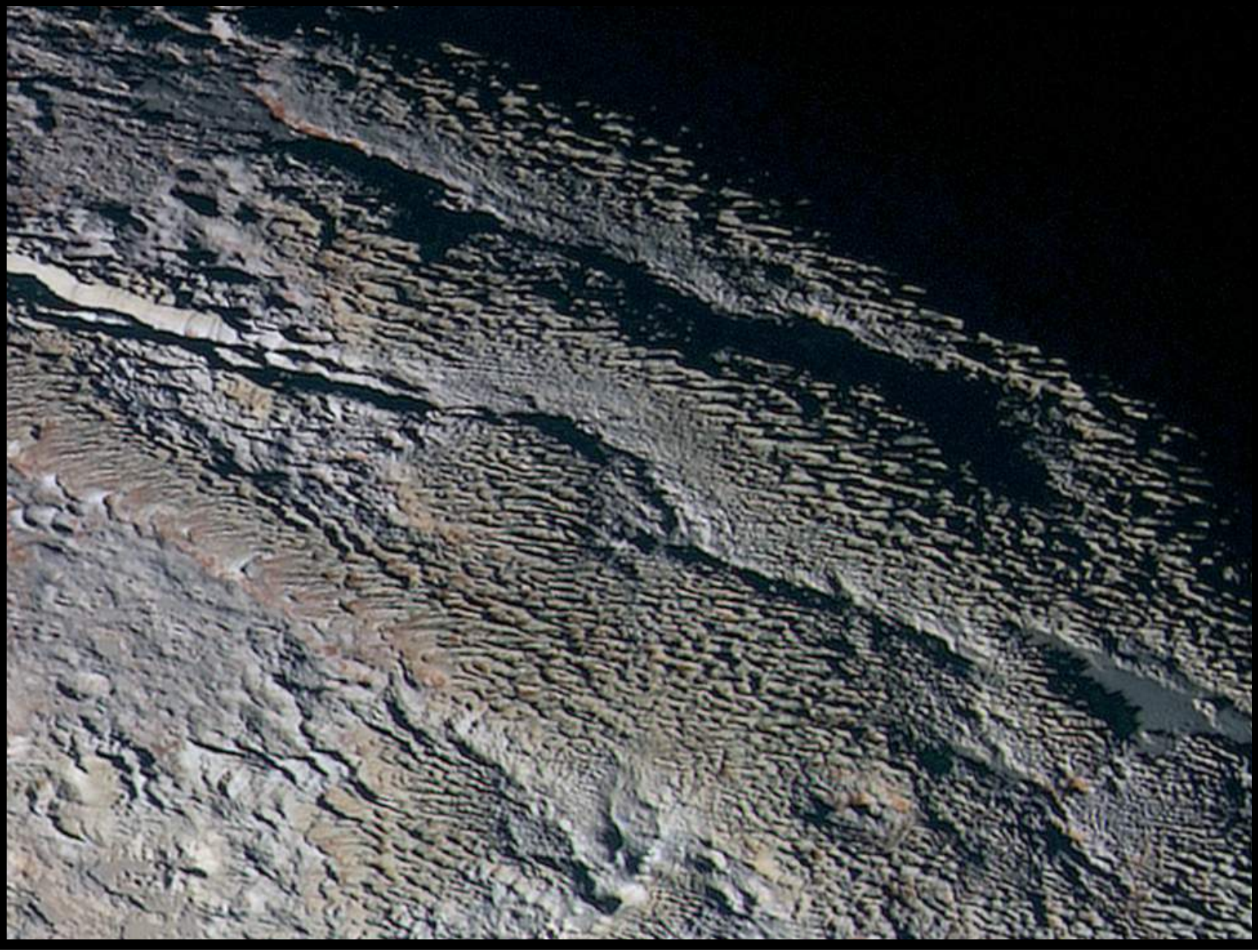


Possible Cryovolcanoes

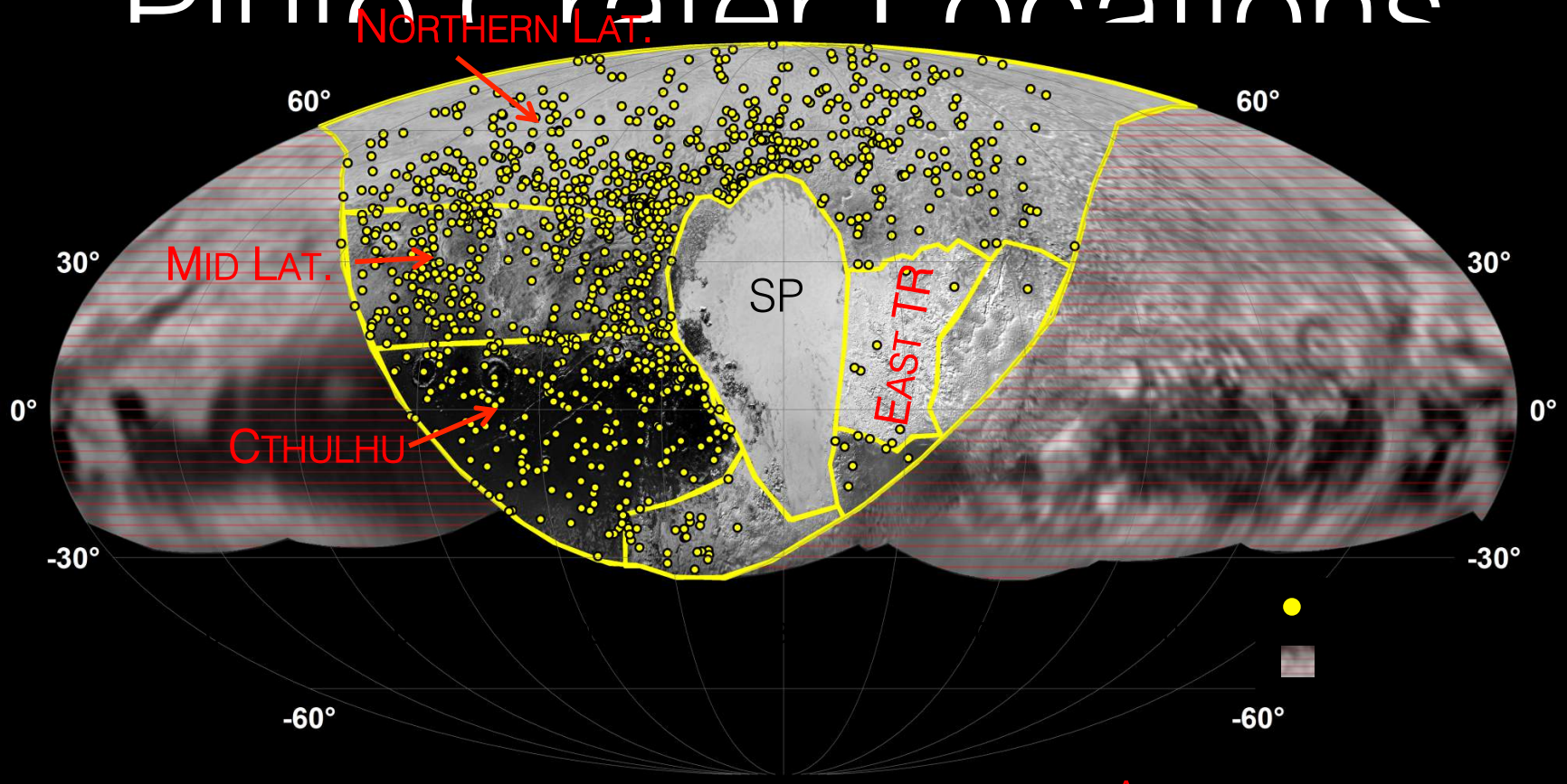




THAT'S JUST WEIRD



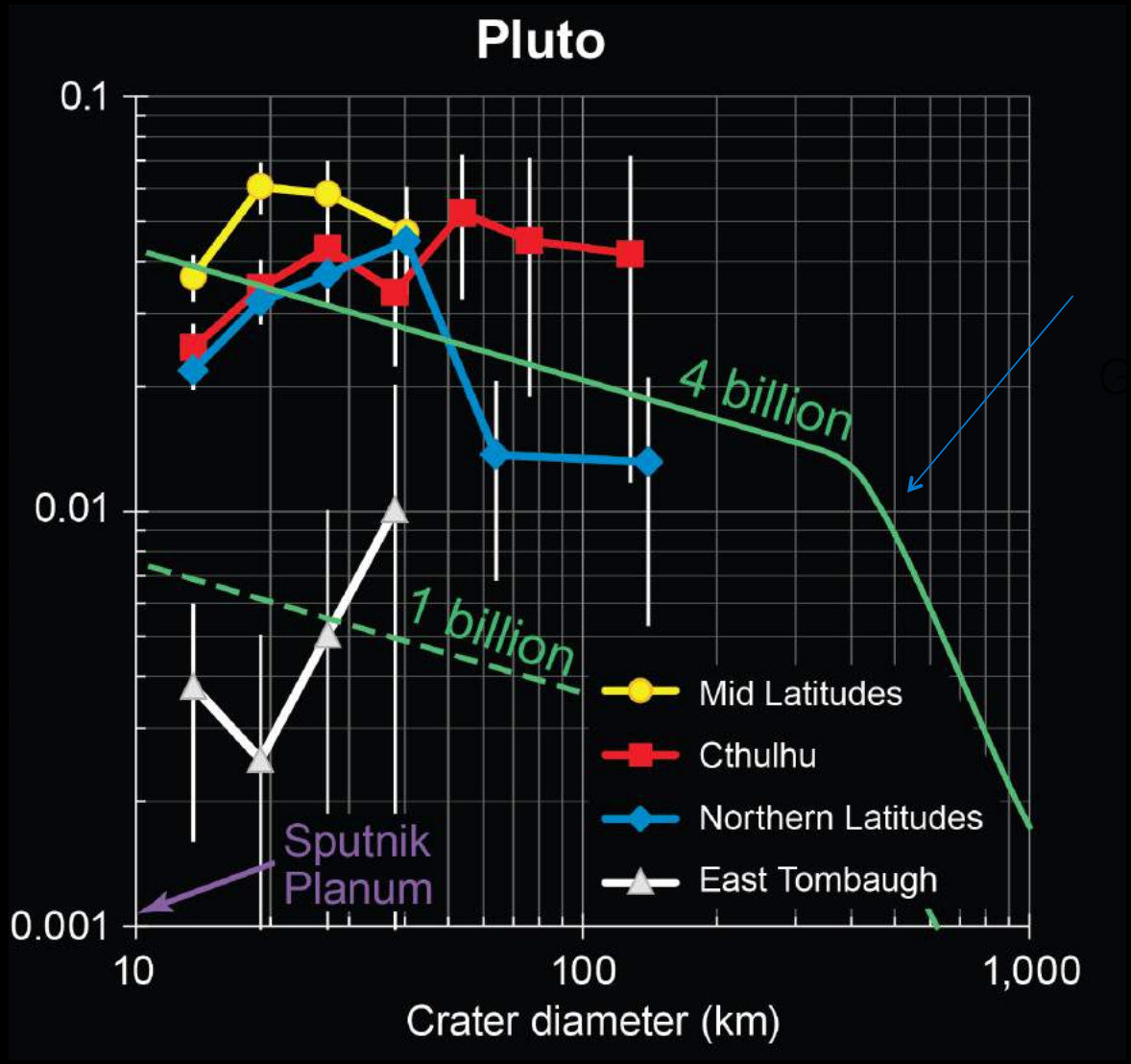
Pluto Crater Locations



ALL NAMES ARE INFORMAL.

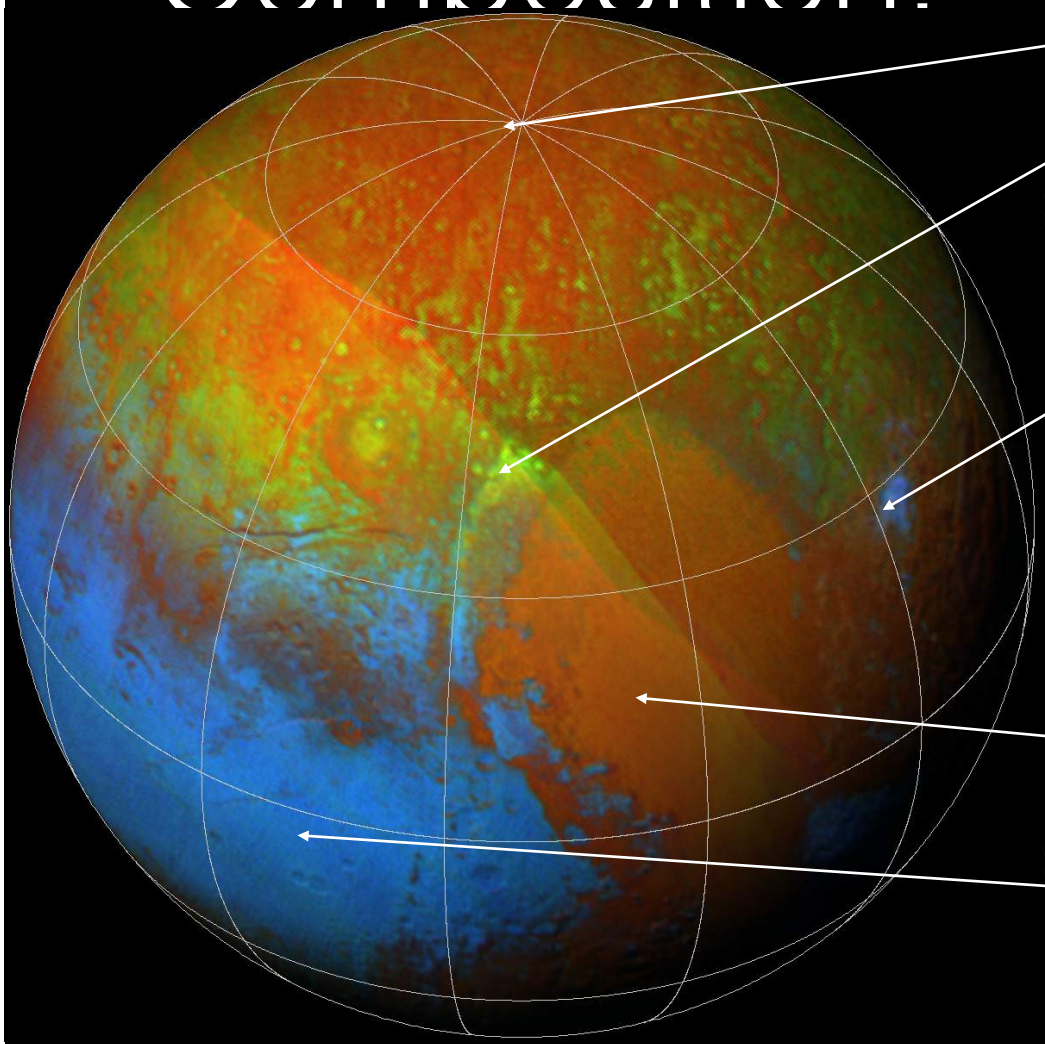
- Mapped at a consistent resolution of ~900 m/px
- 1070 craters on encounter hemisphere
- Cumulative slopes from ~1.8 to 2.5

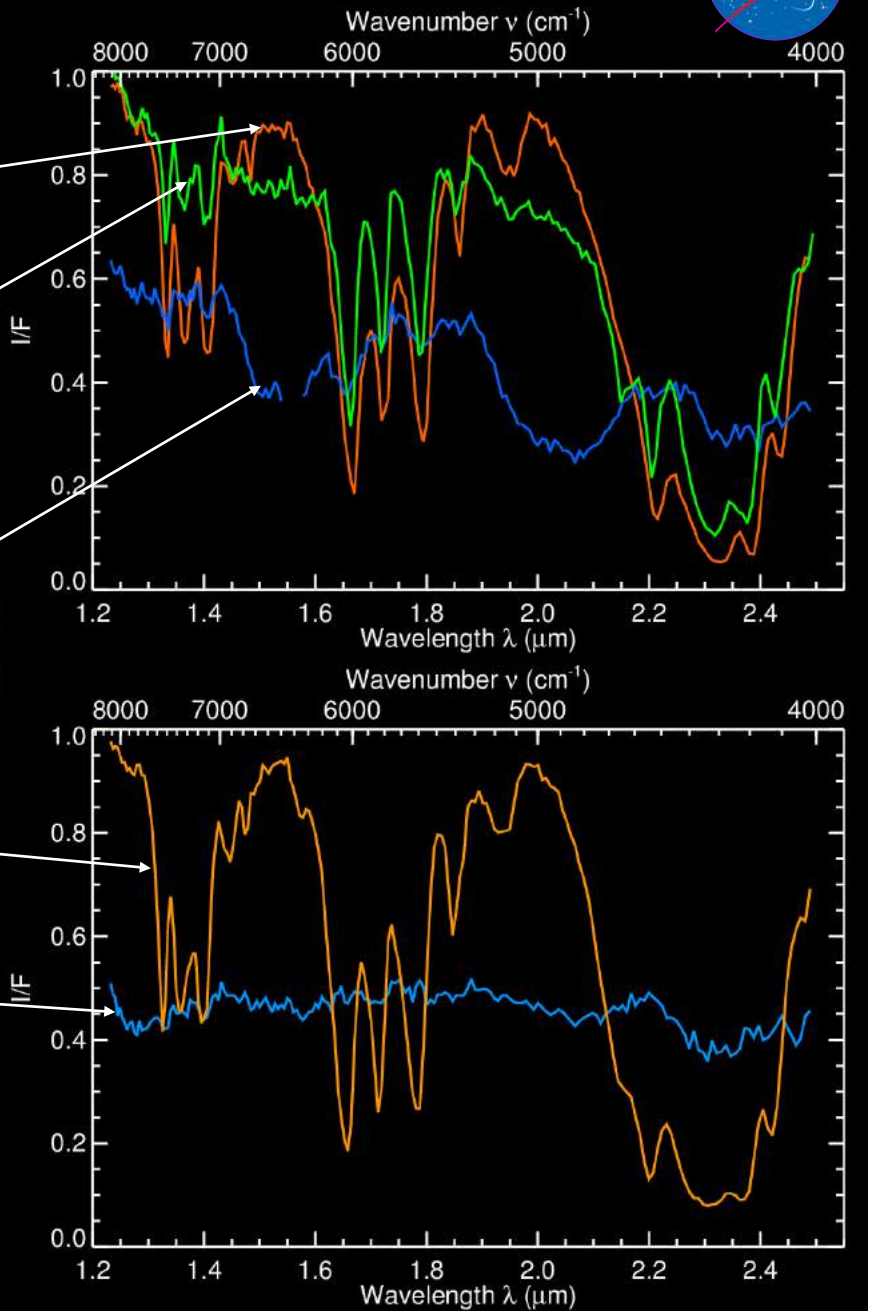
Pluto – How old is old?



Indicates a range from ancient to extremely young surfaces

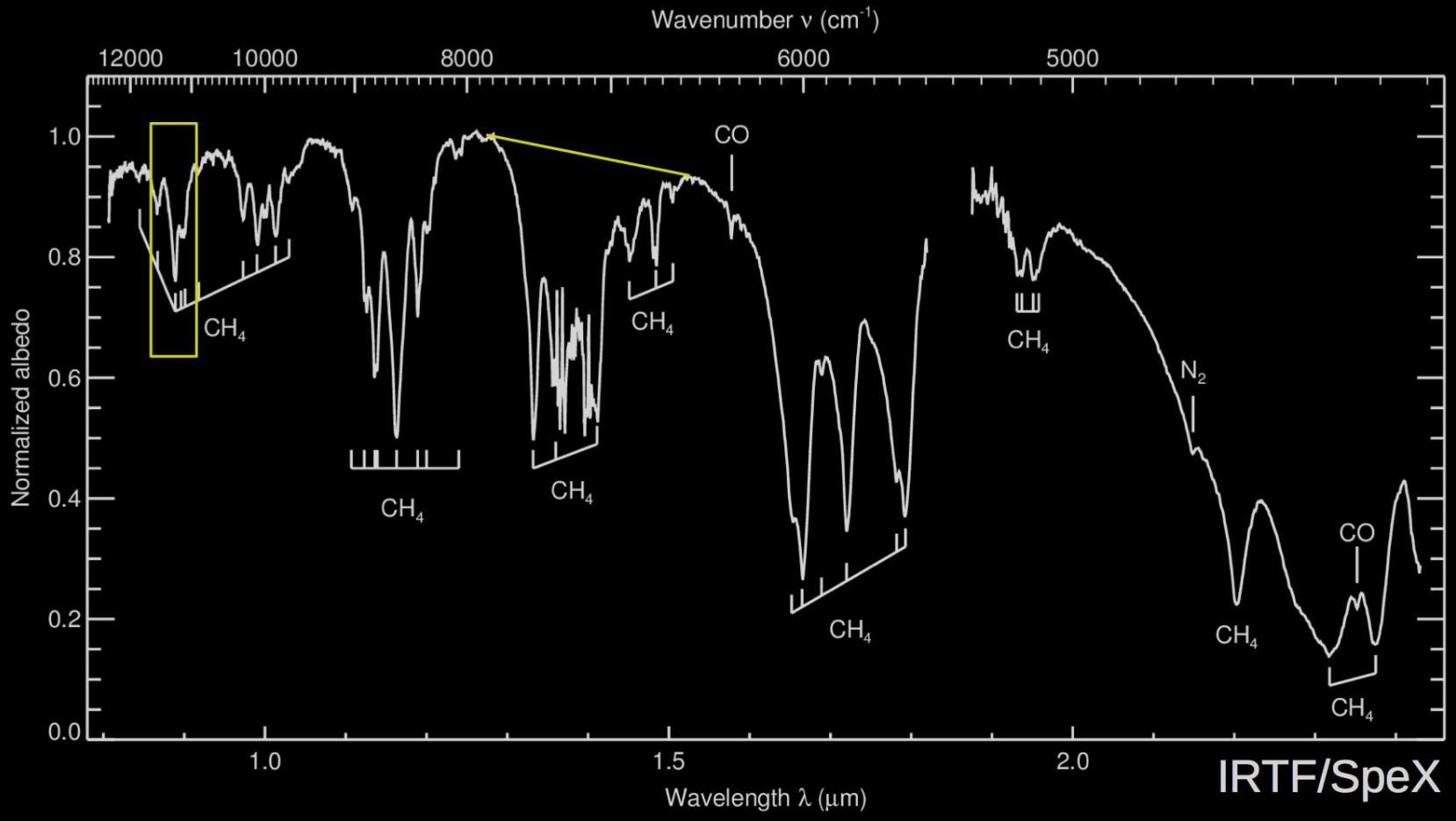
Pluto Composition:

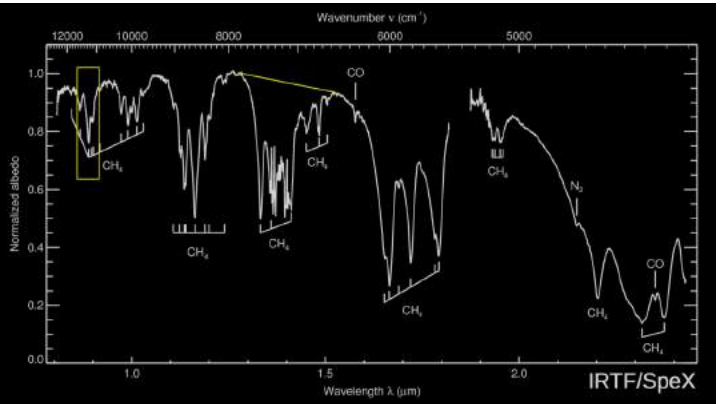




All Pluto system names are informal at this time

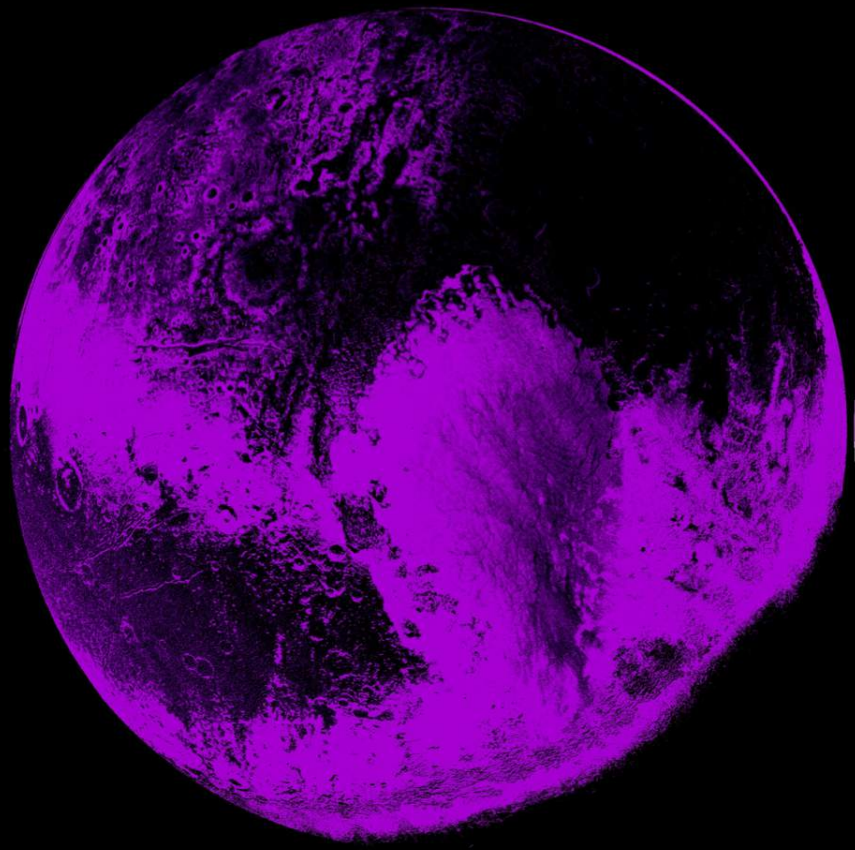
Comparing two bands...

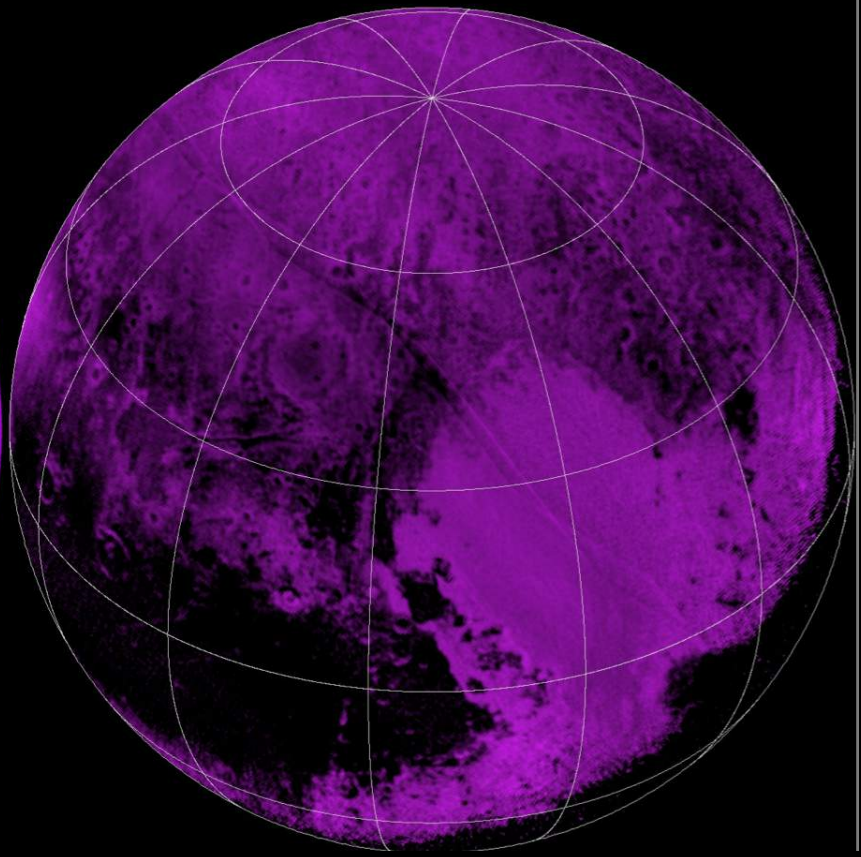




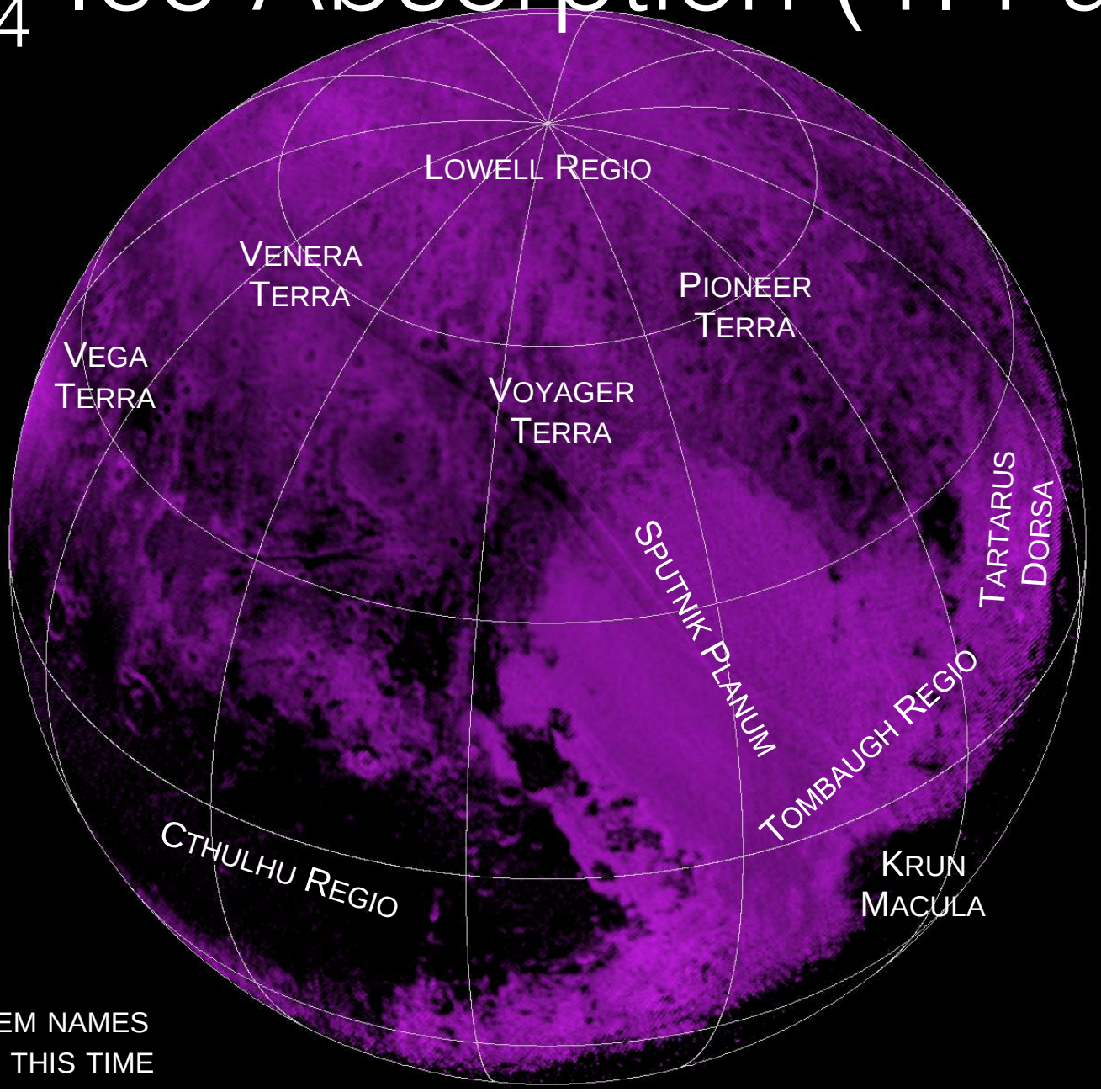
MVIC 0.89 μm

LEISA 1.3-1.4 μm



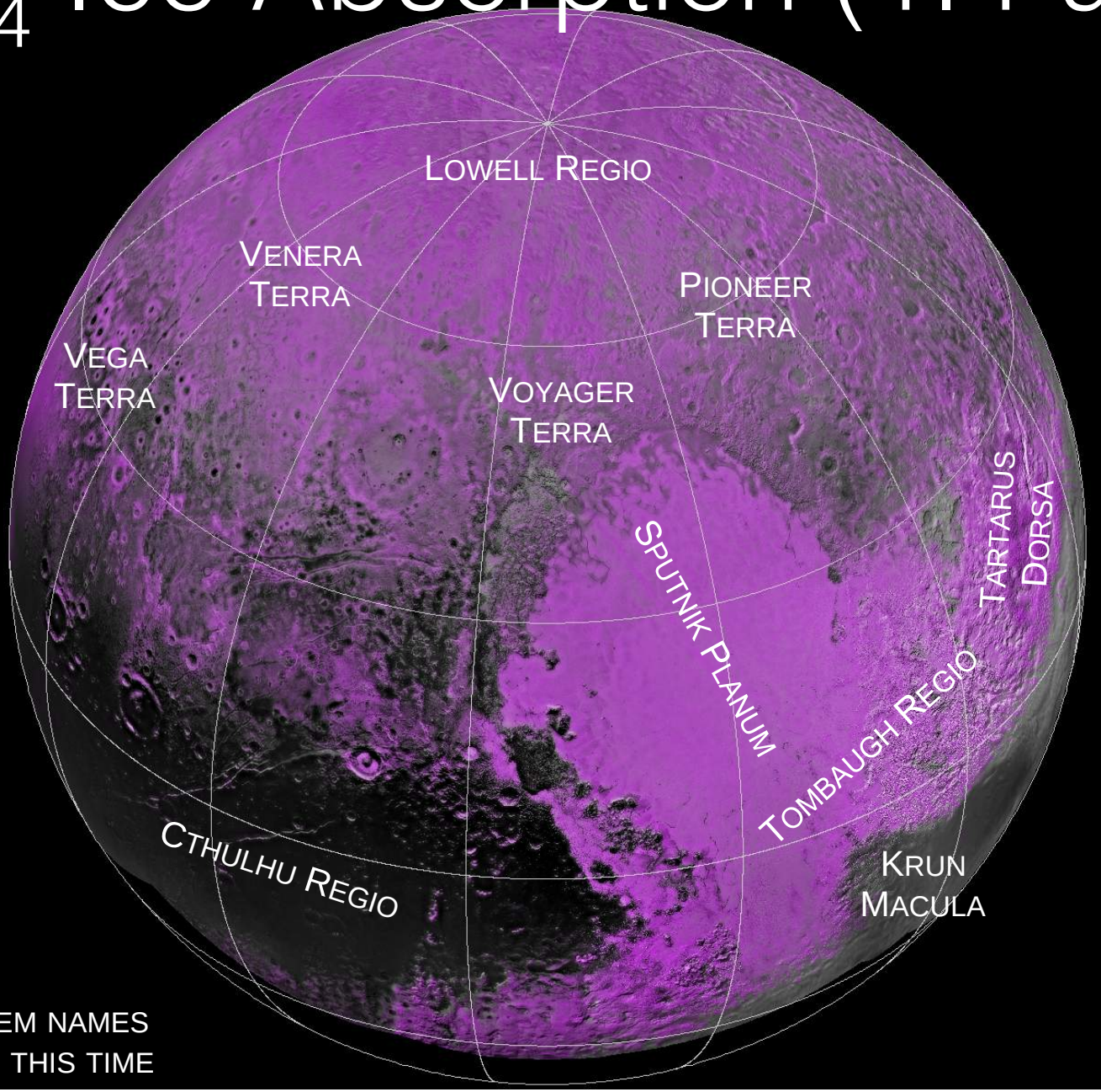


CH_4 Ice Absorption (1.4 um)



All Pluto system names are informal at this time

CH_4 Ice Absorption (1.4 um)



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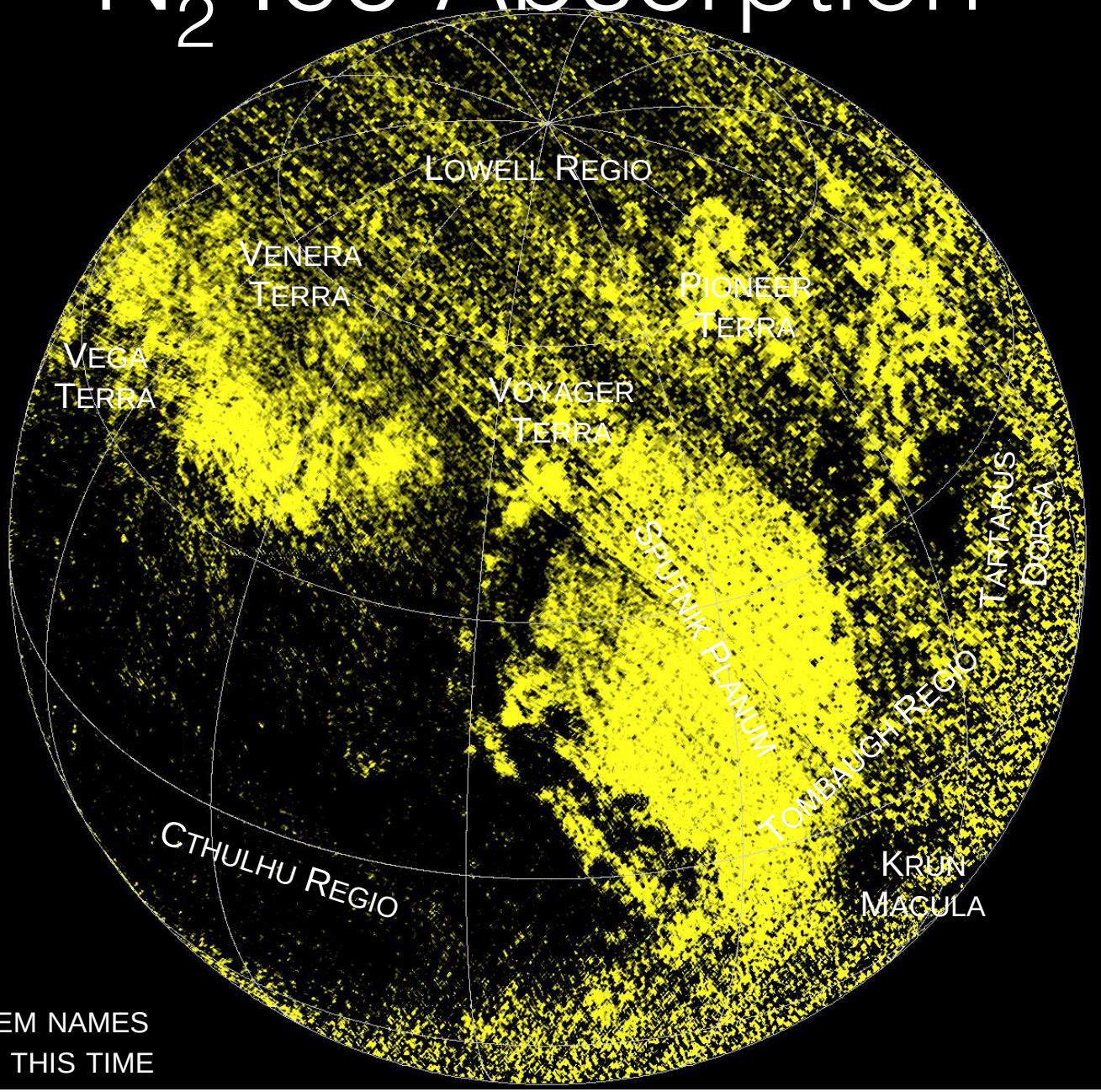
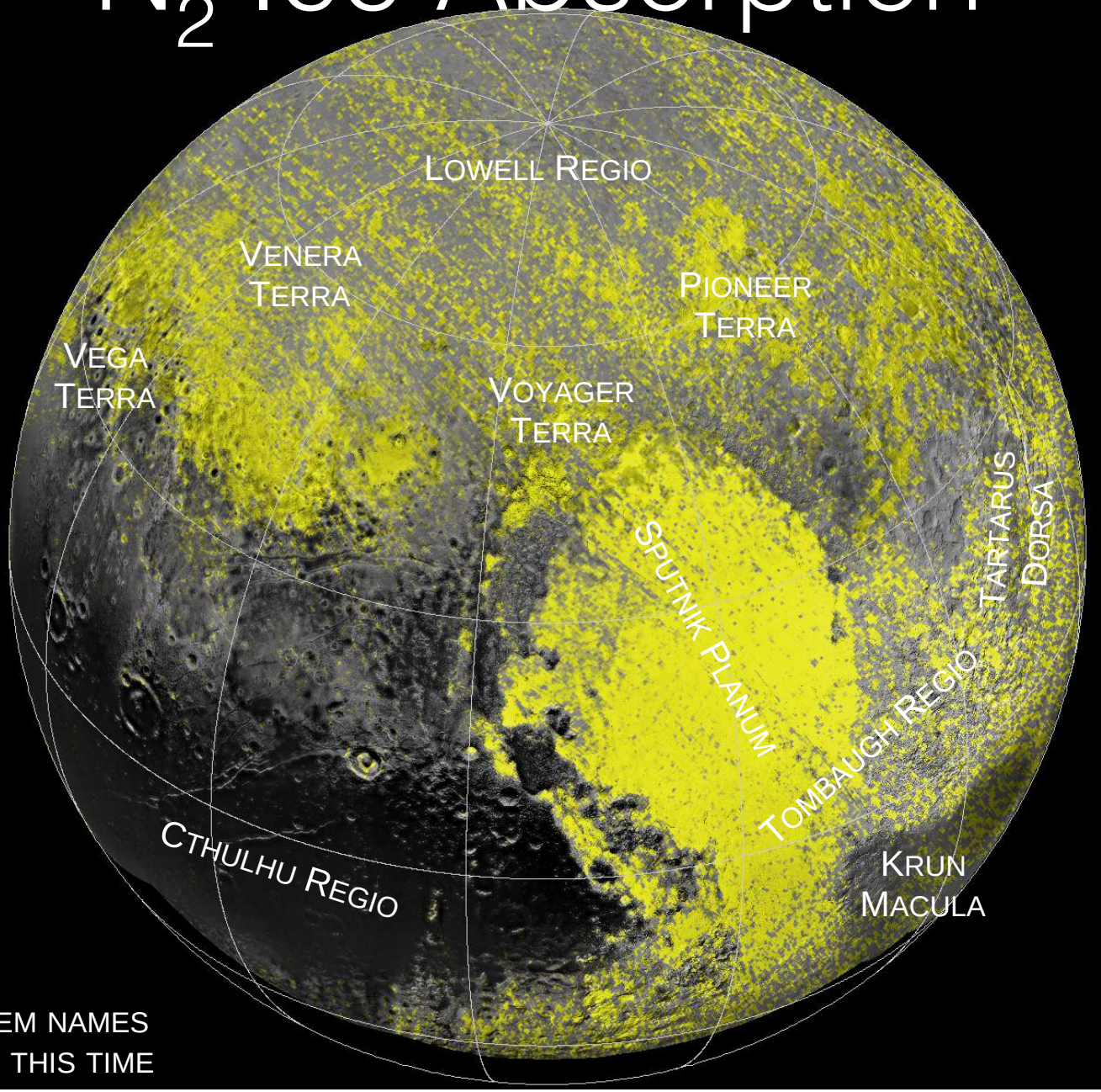
N_2 Ice Absorption



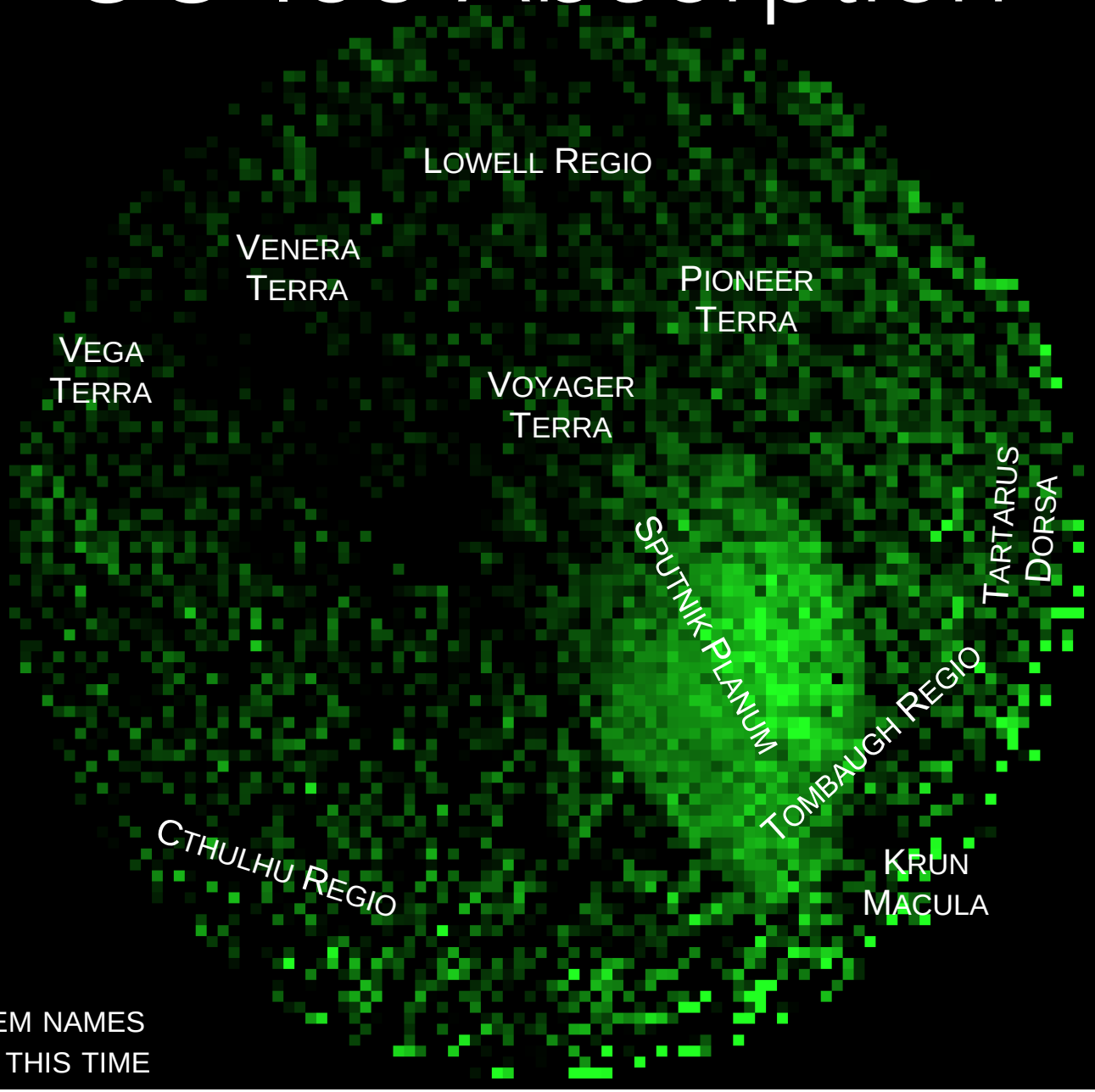
All Pluto system names are informal at this time

N_2 Ice Absorption



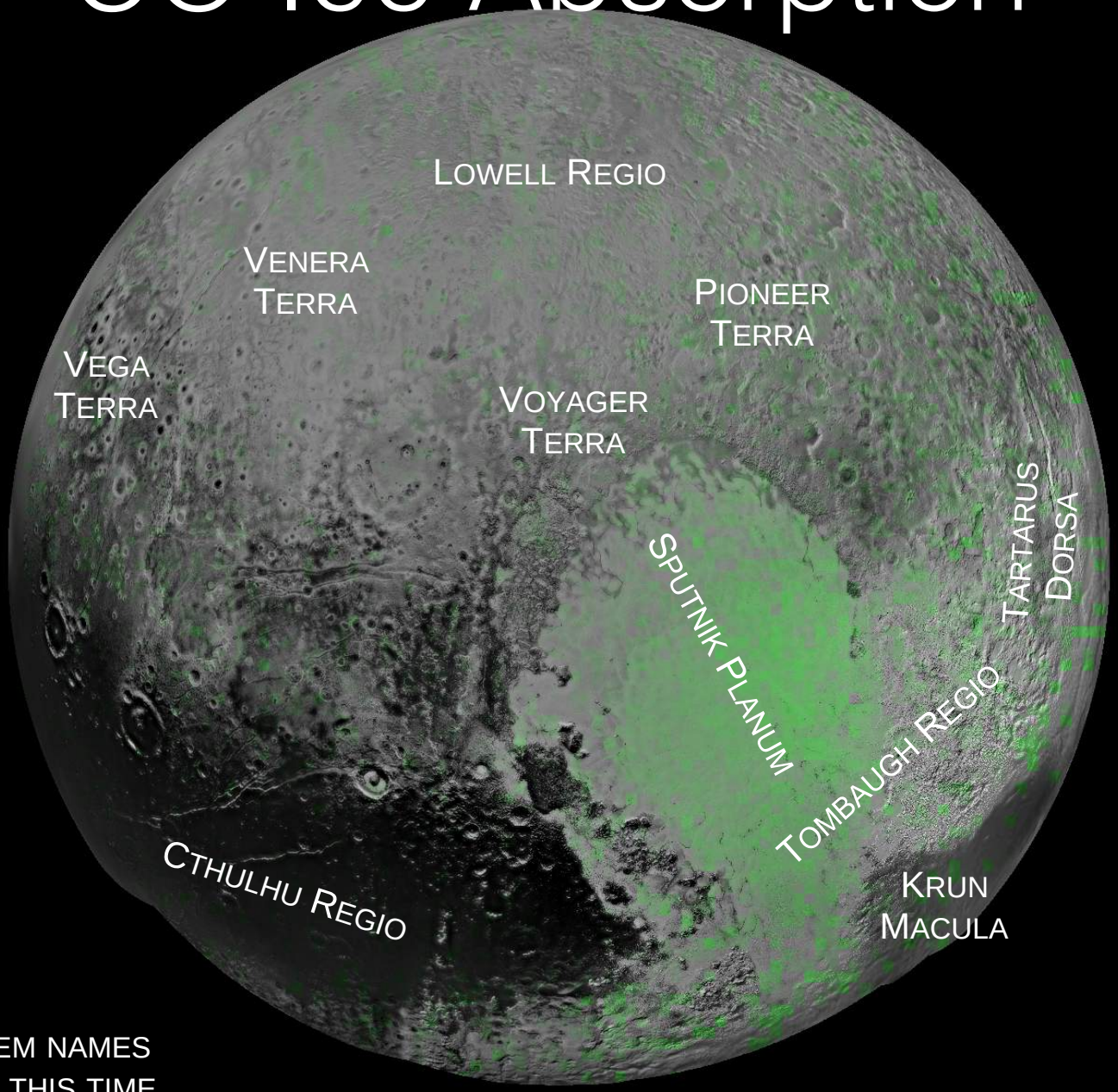
All Pluto system names are informal at this time

CO Ice Absorption



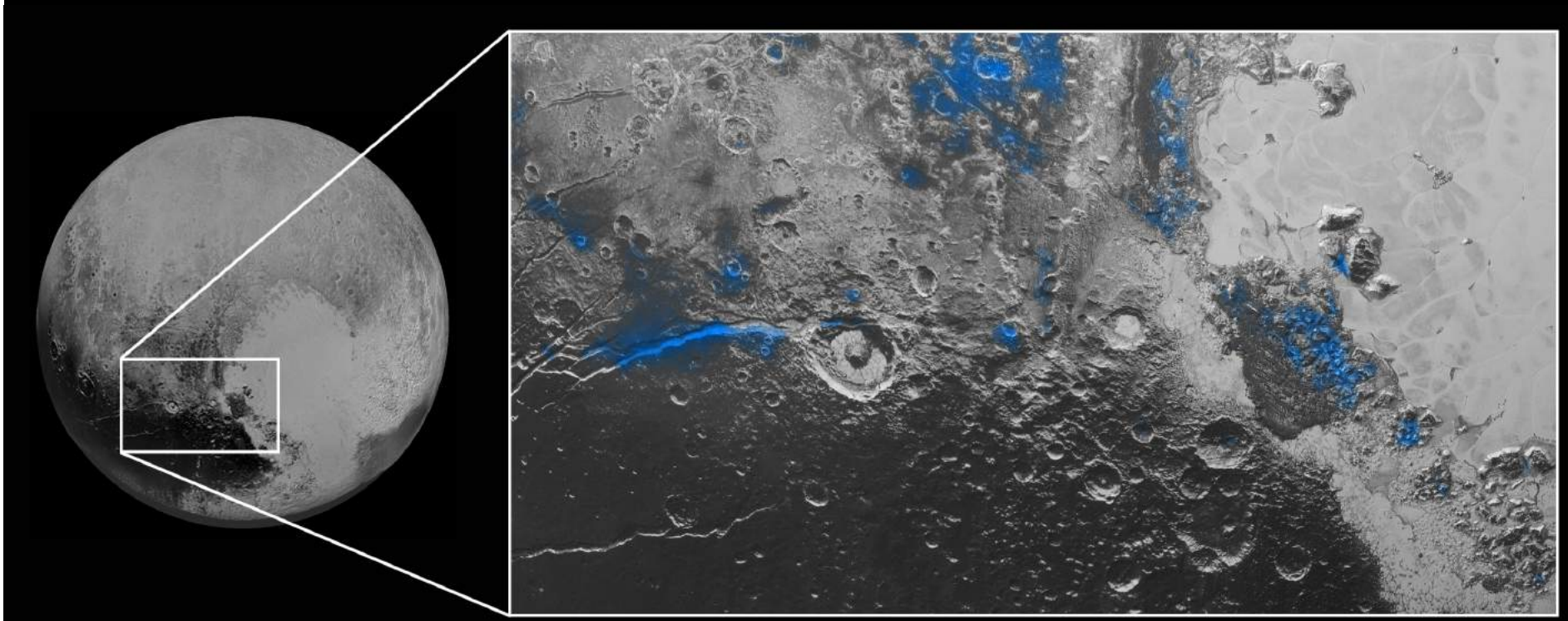
All Pluto system names are informal at this time

CO Ice Absorption



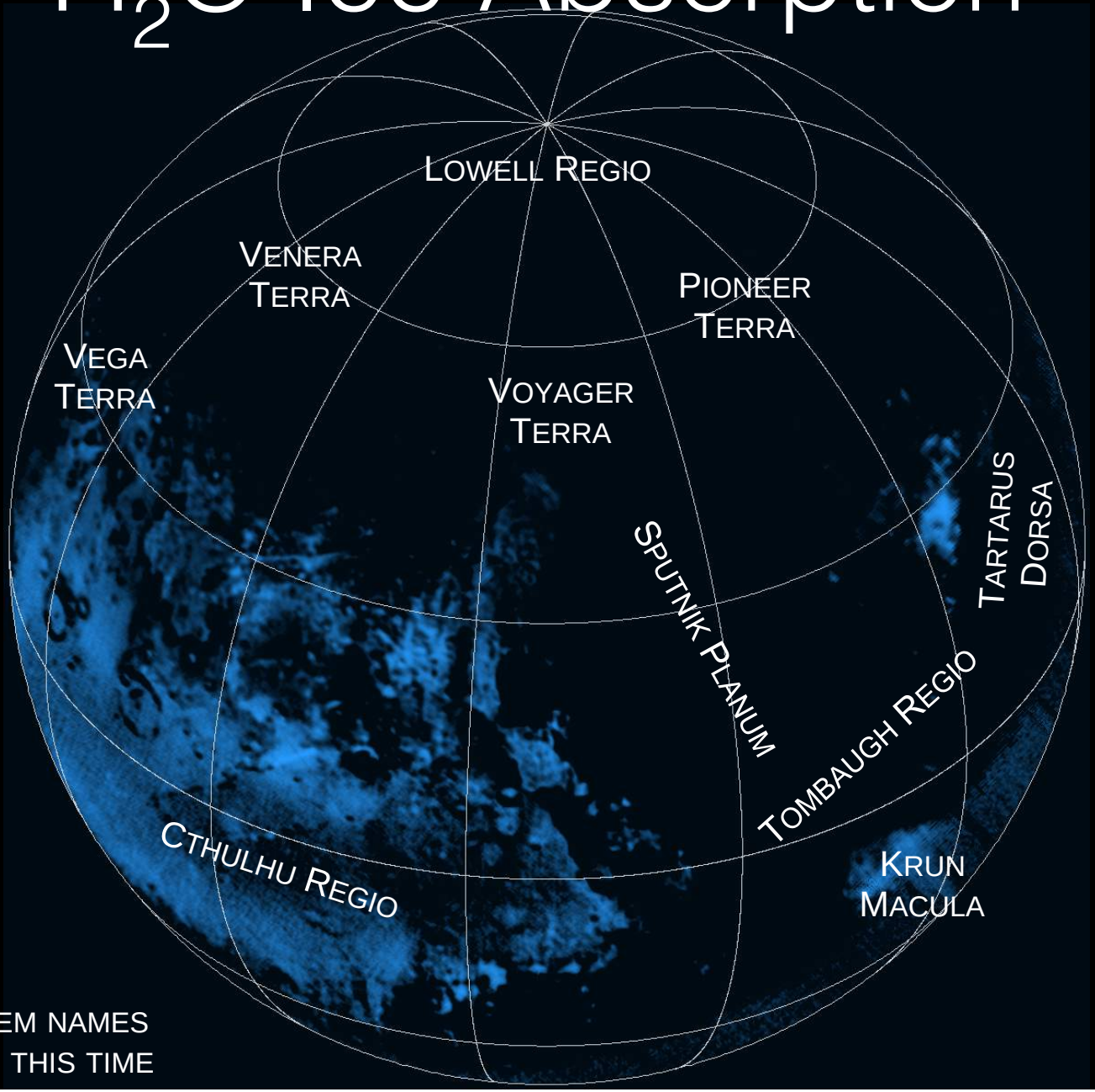
All Pluto system names are informal at this time

LEISA Spectra Show isolated areas nearly "pure" (i.e. Charon-like) water ice



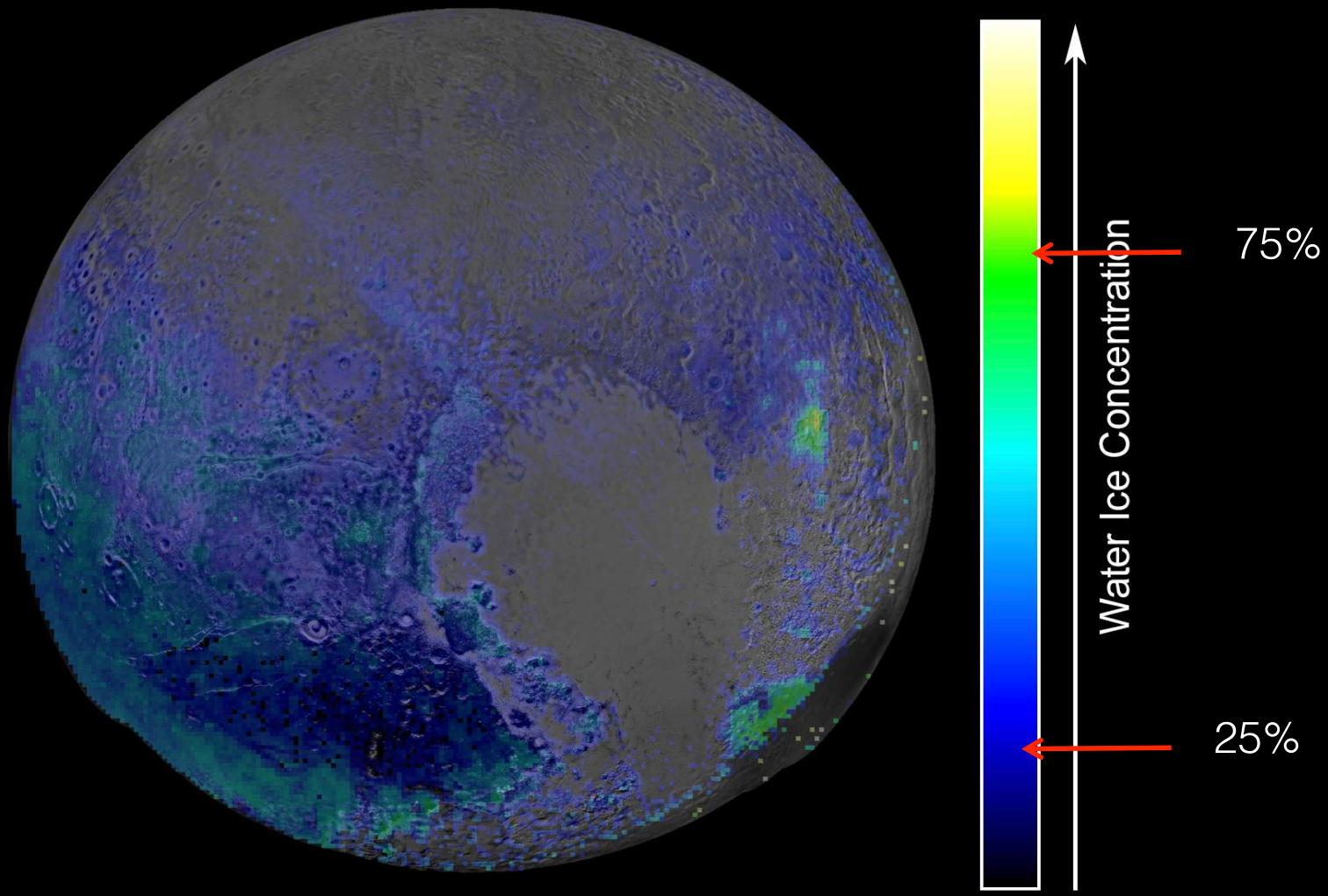
- Blue areas are regions with Charon-like water ice spectra
- This does not mean there is no water in the non-blue areas
  - Water ice could be mixed with other species (e.g. CH_4) or covered by a surface layer of other absorbers

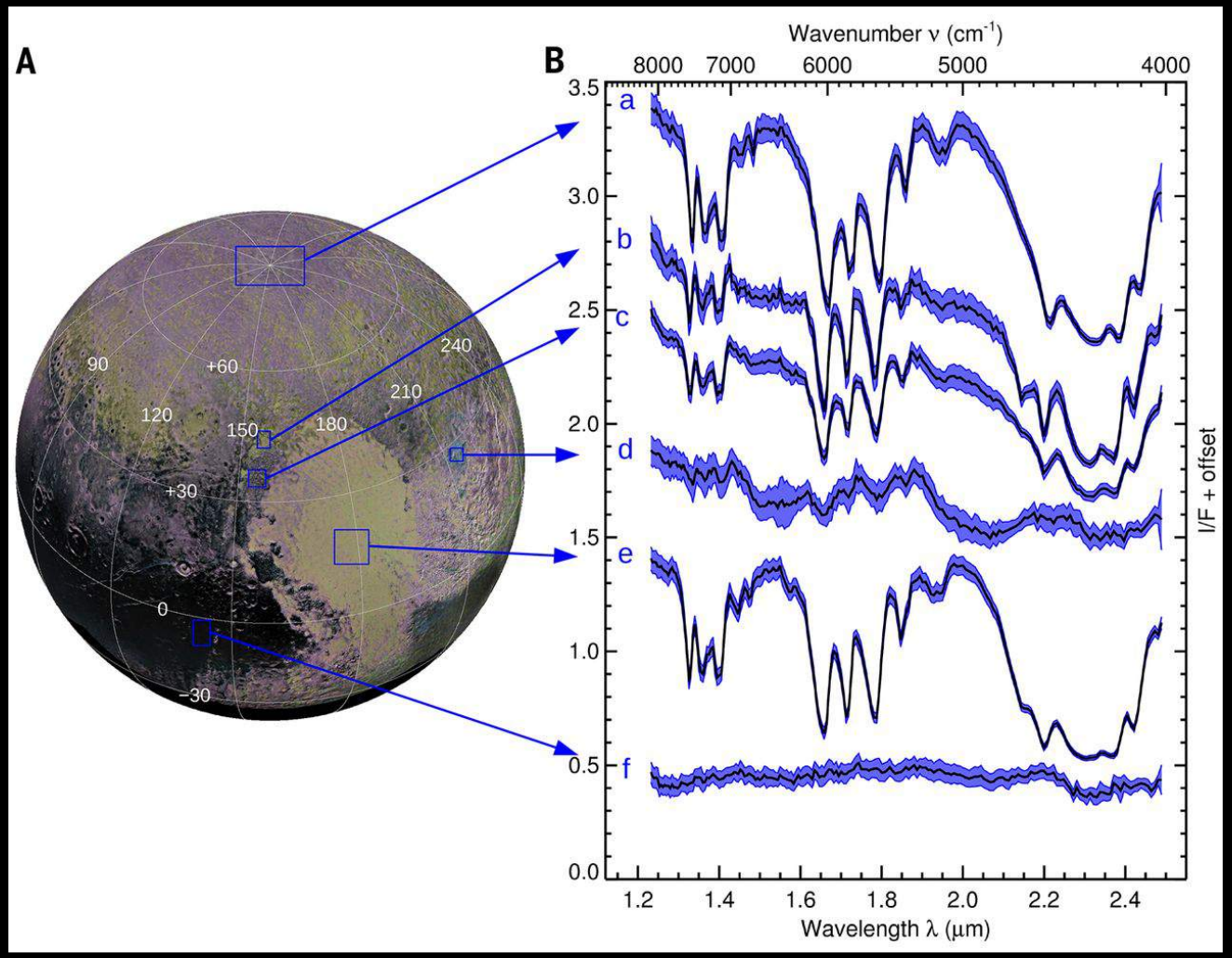
H_2O Ice Absorption



All Pluto system names are informal at this time

H_2O Ice Absorption from more detailed modeling

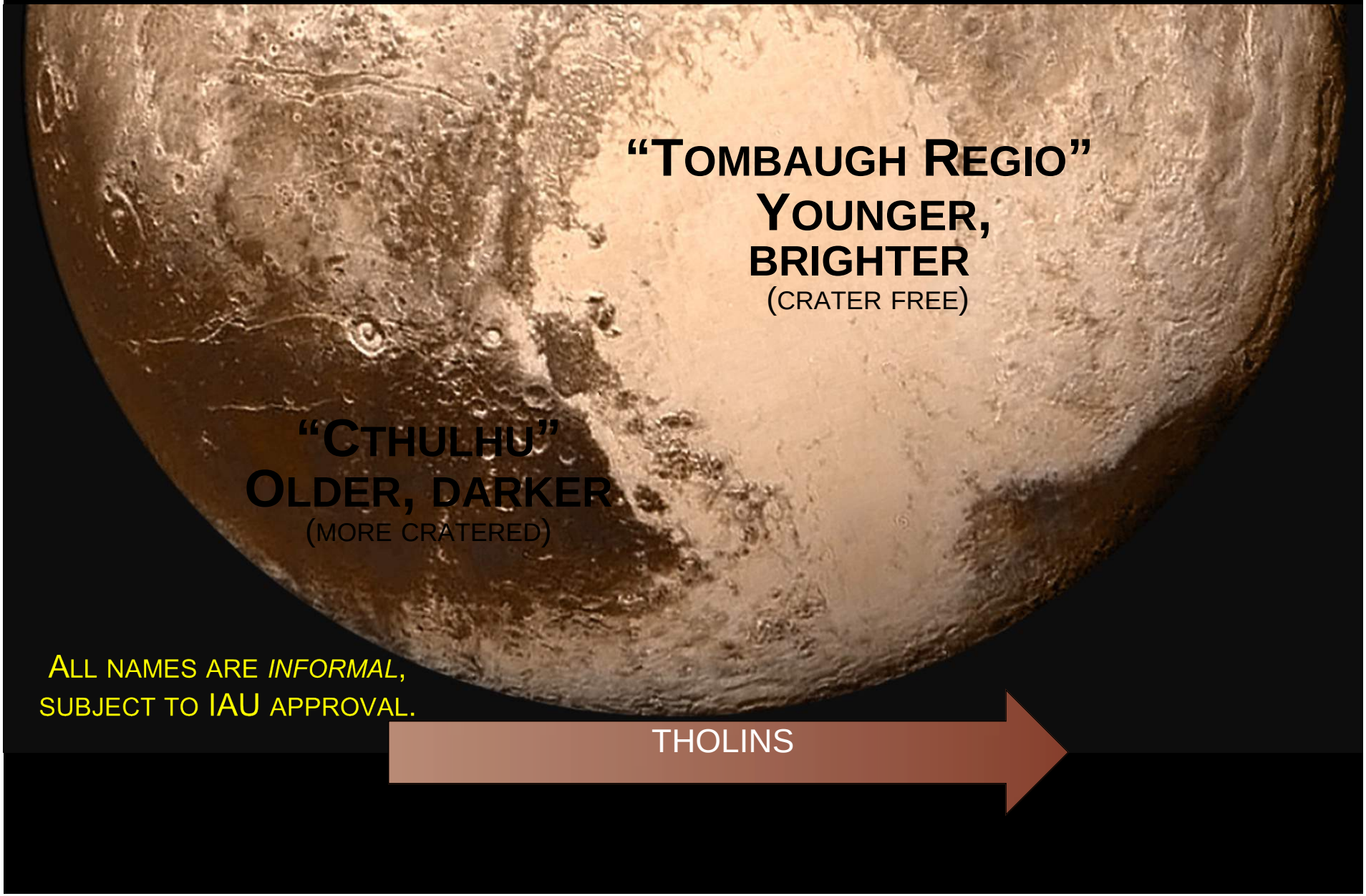




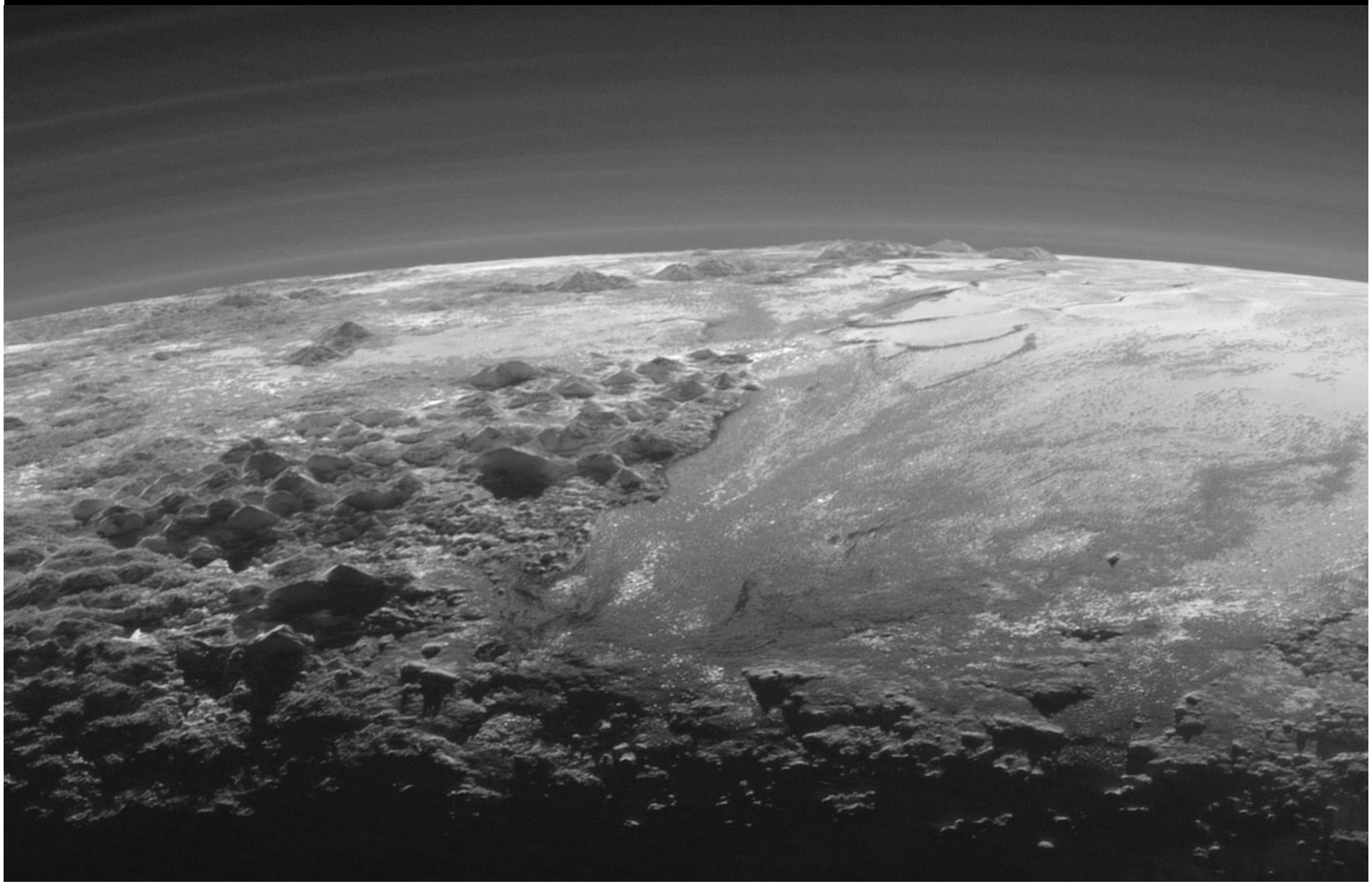
Science

AAAS

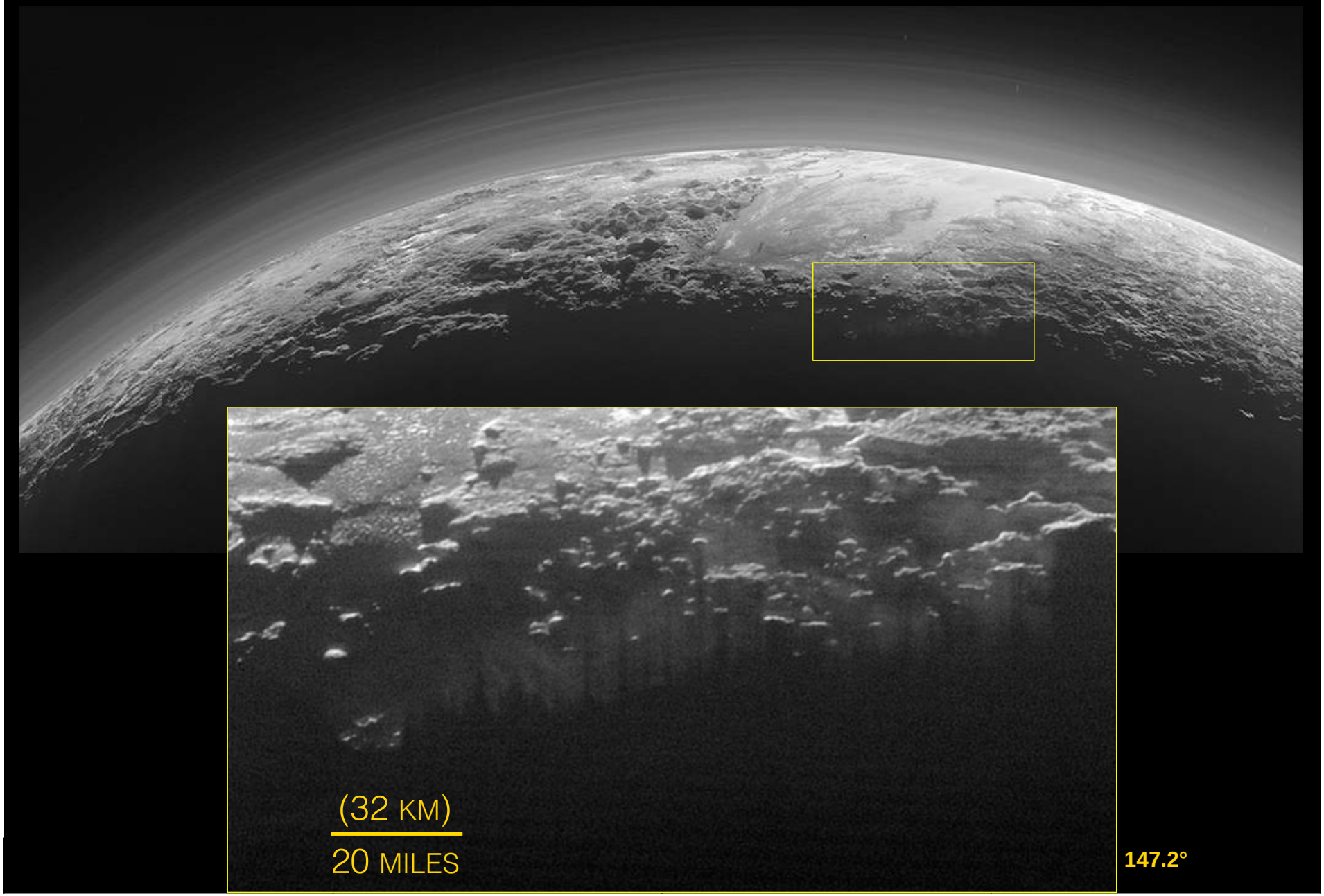
WHY IS PLUTO RED ?



MVIC pan Image taken soon after closest approach
You are there!



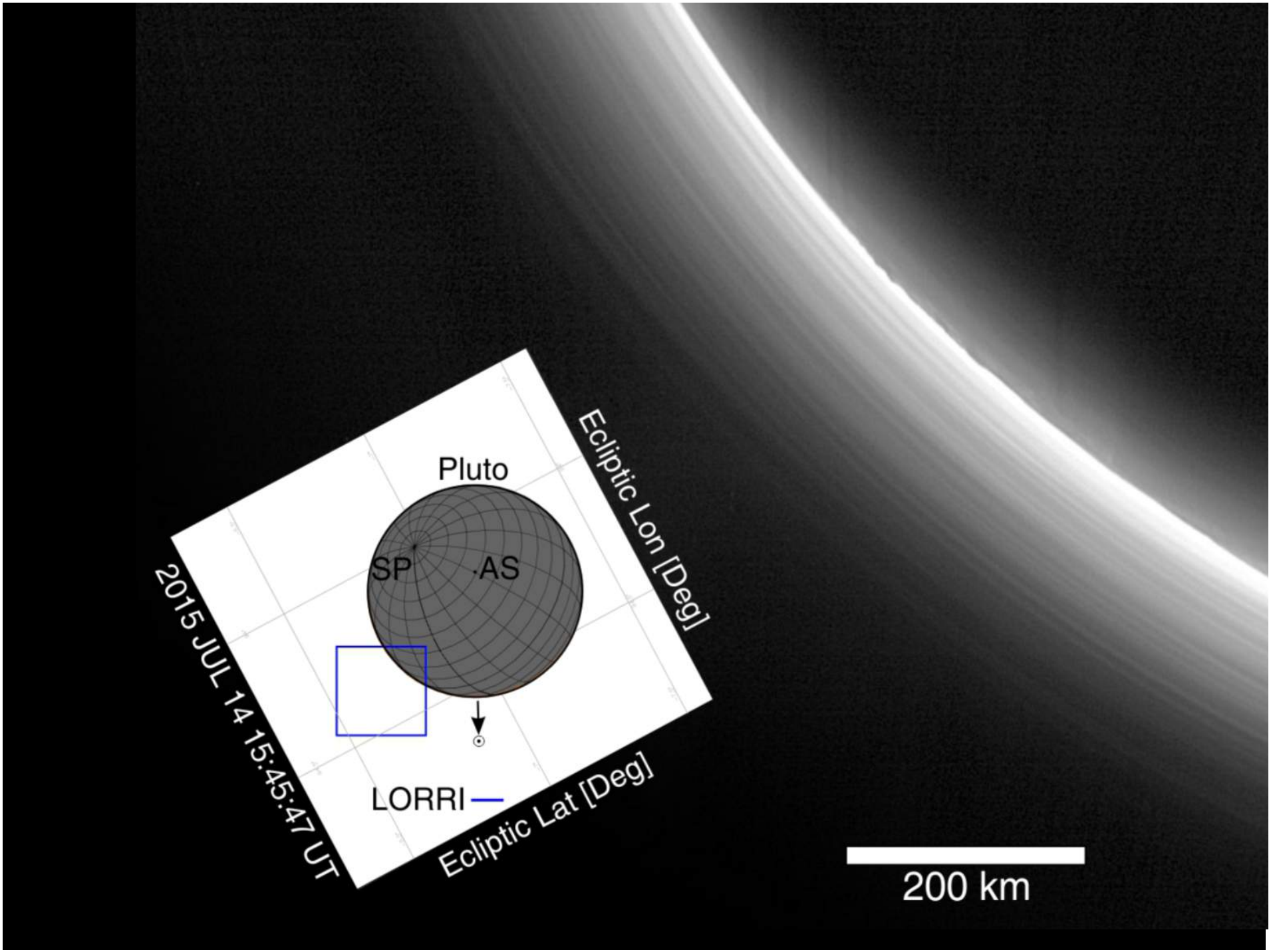
CREPUSCULAR RAYS SHOW MOUNTAINOUS TERRAIN



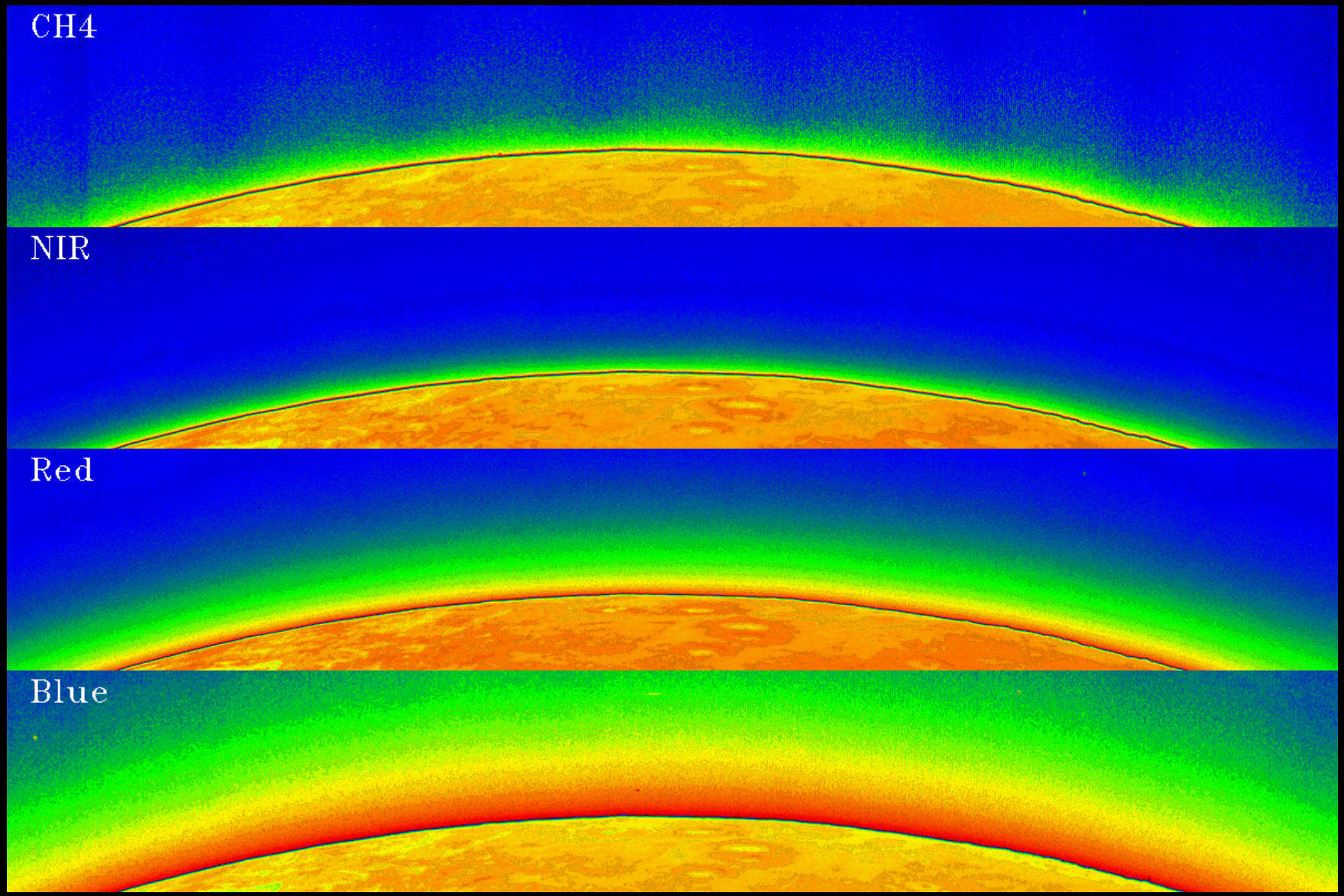
MVIC color Image of Pluto's haze layers on departure

HAZES PROBABLY INVOLVE SUNLIGHT INITIATED CHEMICAL REACTIONS OF NITROGEN AND METHANE, LEADING TO RELATIVELY SMALL, SOOT-LIKE PARTICLES THAT GROW AS THEY SETTLE TOWARD THE SU RFACE.

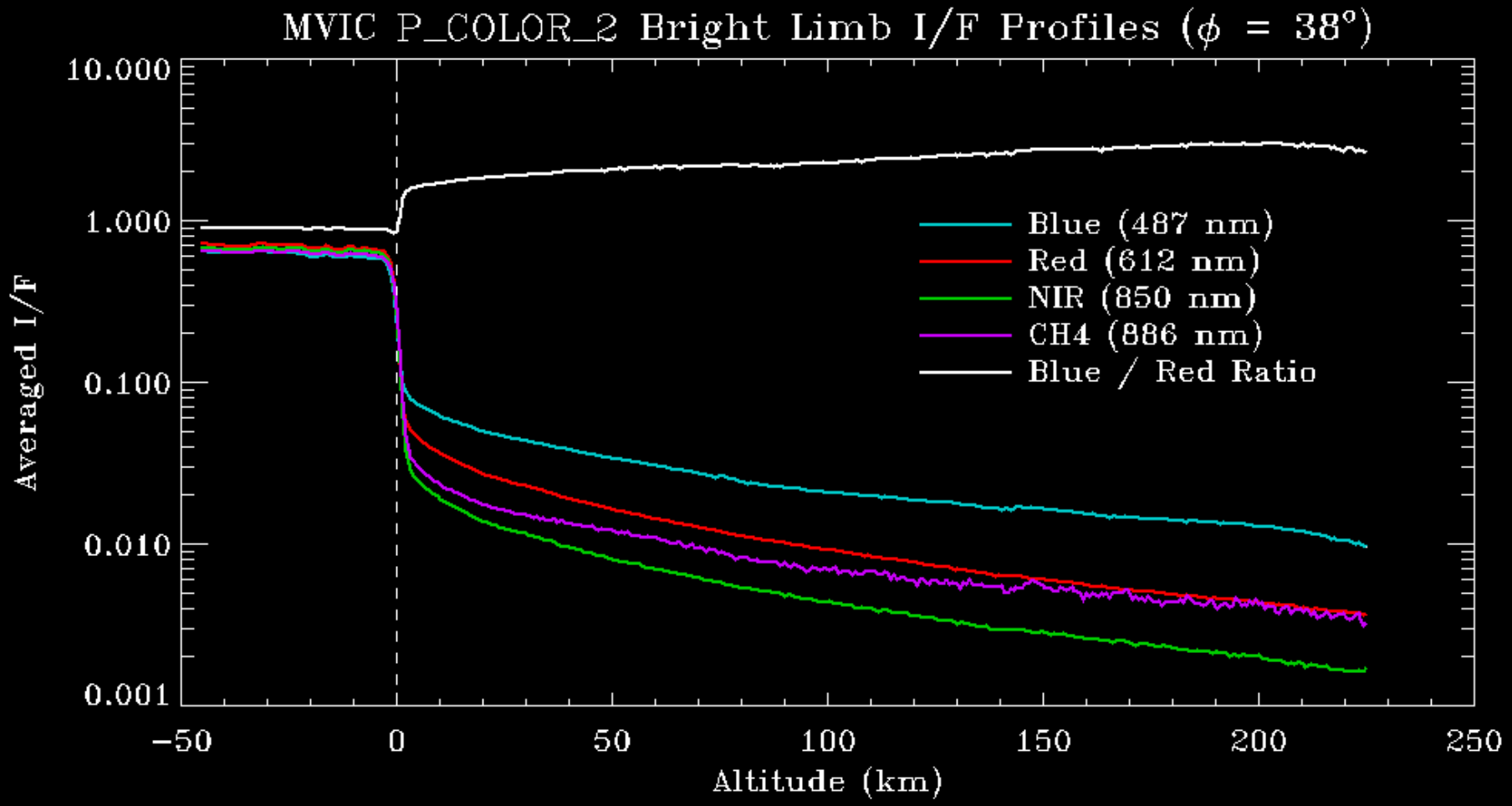
THE PARTICLES EXTEND SEVERAL HUNDRED KM ABOVE THE SURFACE AND ARE STRONGLY FOR WARD SCATTERING IN THE MVIC BLUE CHAN NEL


Pluto
SP
AS
LORRI
2015 JUL 14 15:45:47 UT
Ecliptic Lon [Deg]
Ecliptic Lat [Deg]
200 km

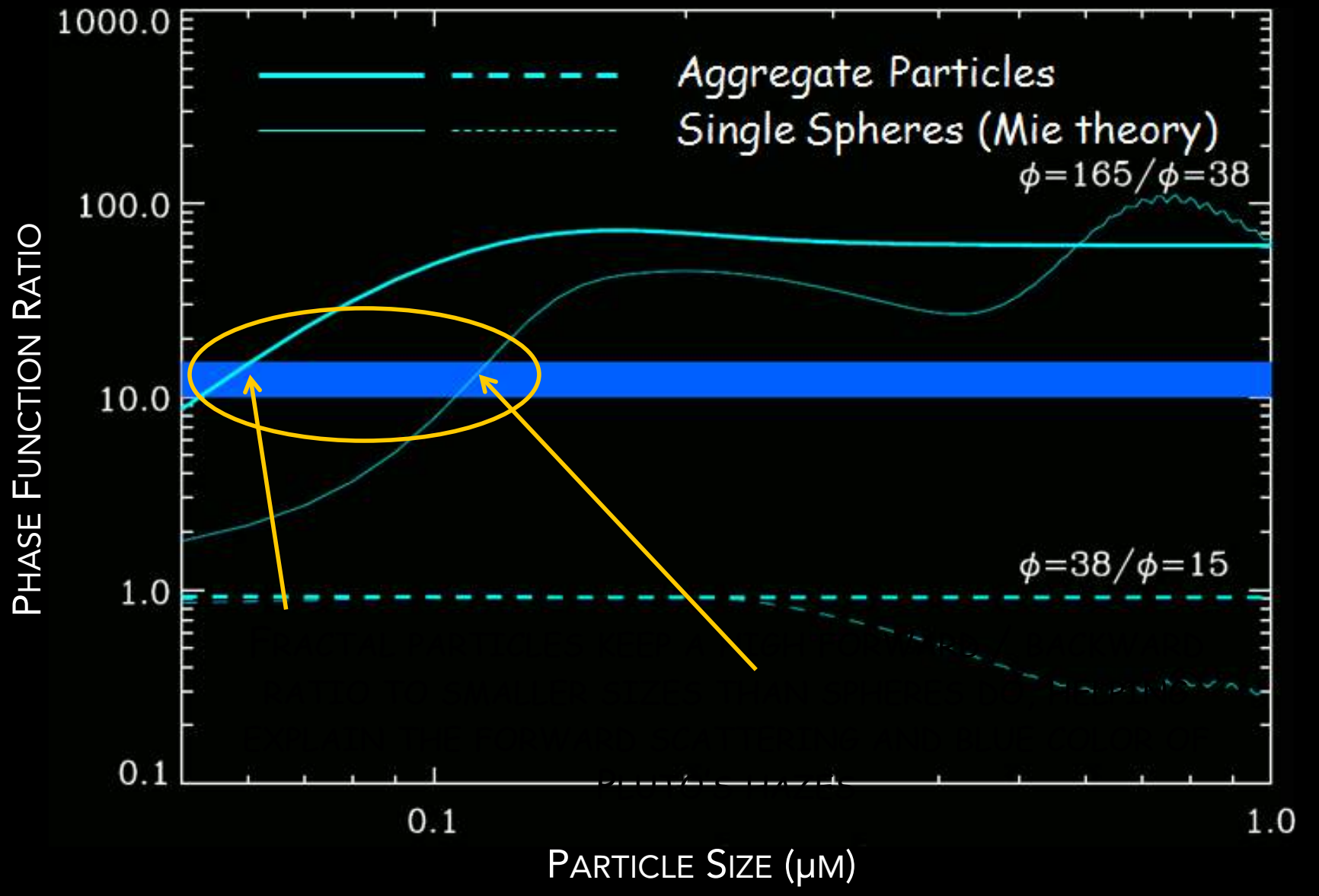
MVIC Haze I/F On Approach



MVIC Haze I/F Profiles

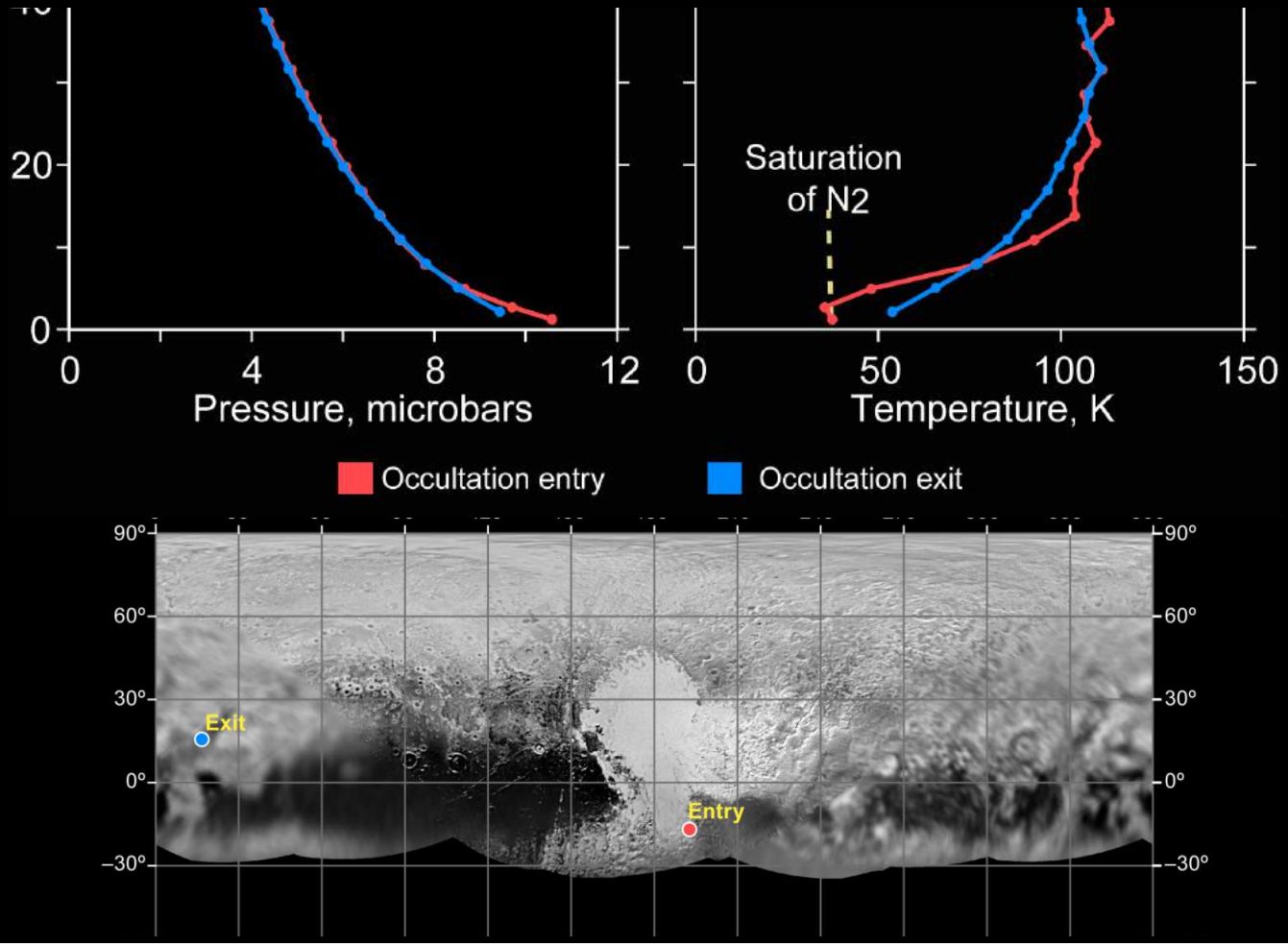


Haze Scattering Properties

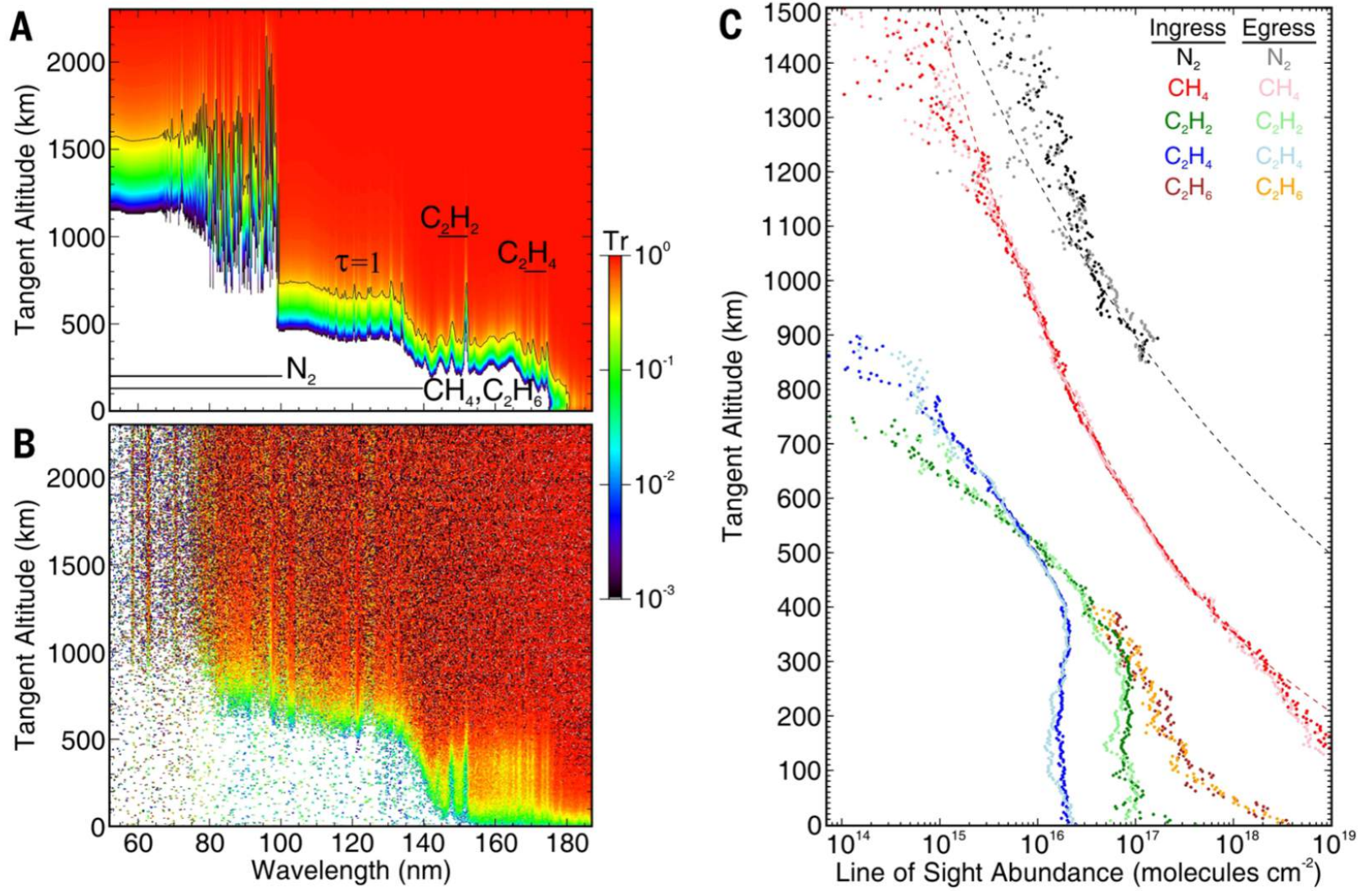


Pluto's Lower Atmosphere

- The REX uplink radio occultation results show a surface pressure of 11 μbars at ingress and 10 μbars at egress
- The lowest 4 km at ingress are close to the solid-vapor equilibrium temperature of N_2 at Pluto's surface pressure



Solar Occultation



CHARON'S RED *ZUCHETTO*
"SKULL CAP"

NATURAL COLOR
(RALPH + LORRI)

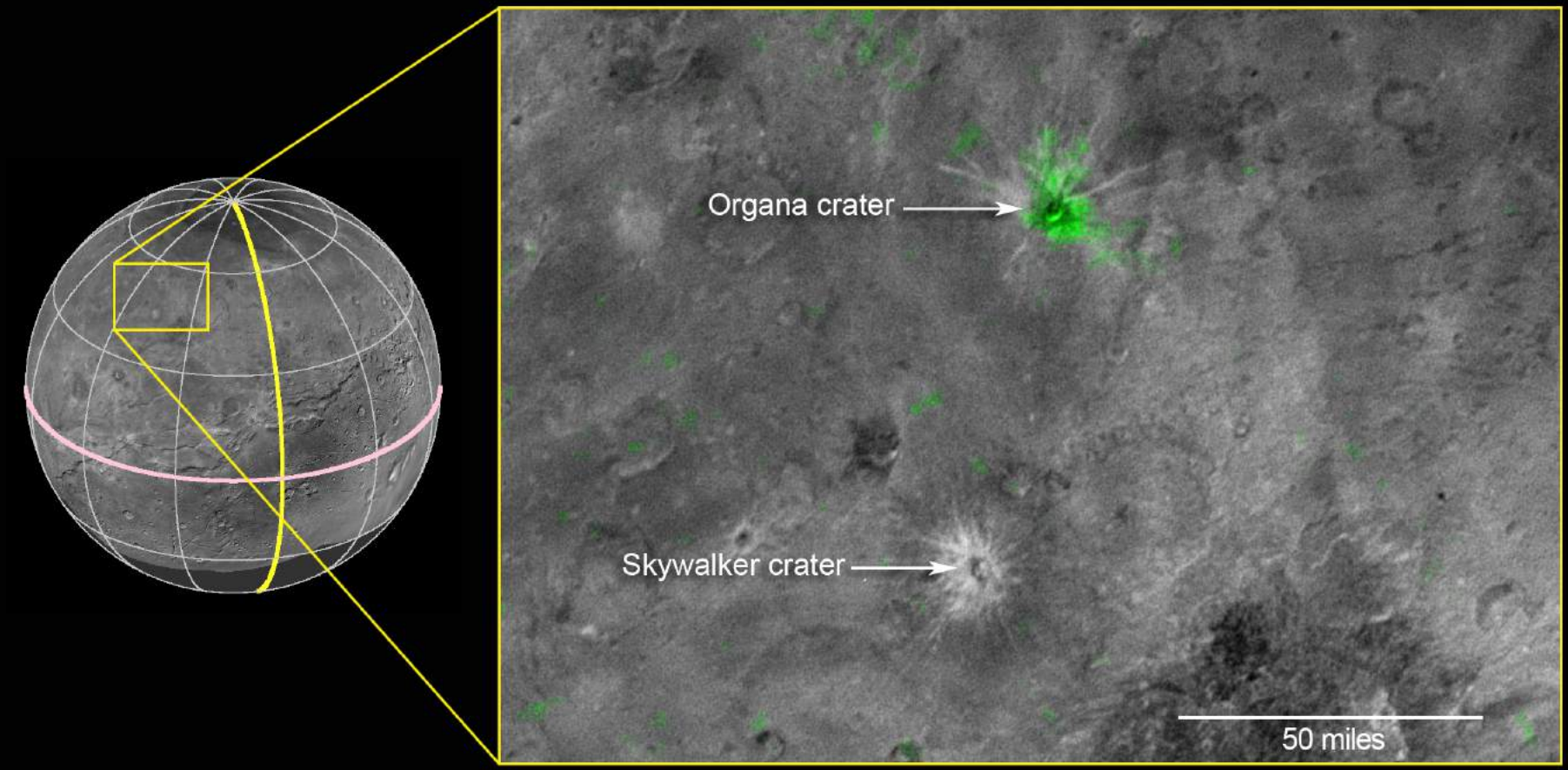
ENHANCED COLOR
(RALPH)

DARK POLAR SPOT IS REDDER THAN CHARON AVERAGE

RED TERRAIN EXTENDS BEYOND DARK CORE OF SPOT

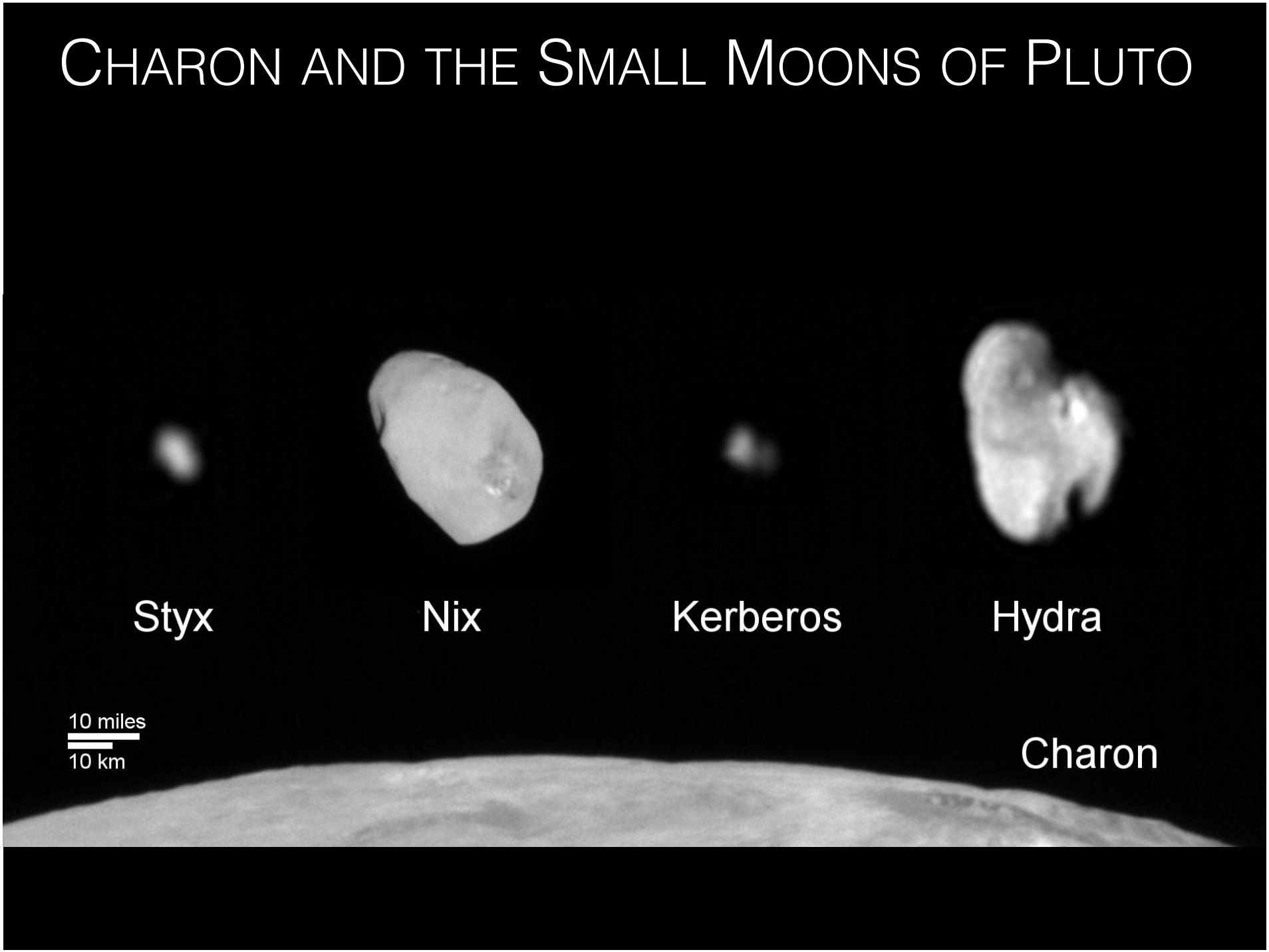
DARK CORE MAY BE CORRELATED WITH GEOLOGIC STRUCTURES

CHARON COMPOSITION: NH_3 RICH REGIONS MAY INDICATE NEWER FEATURES



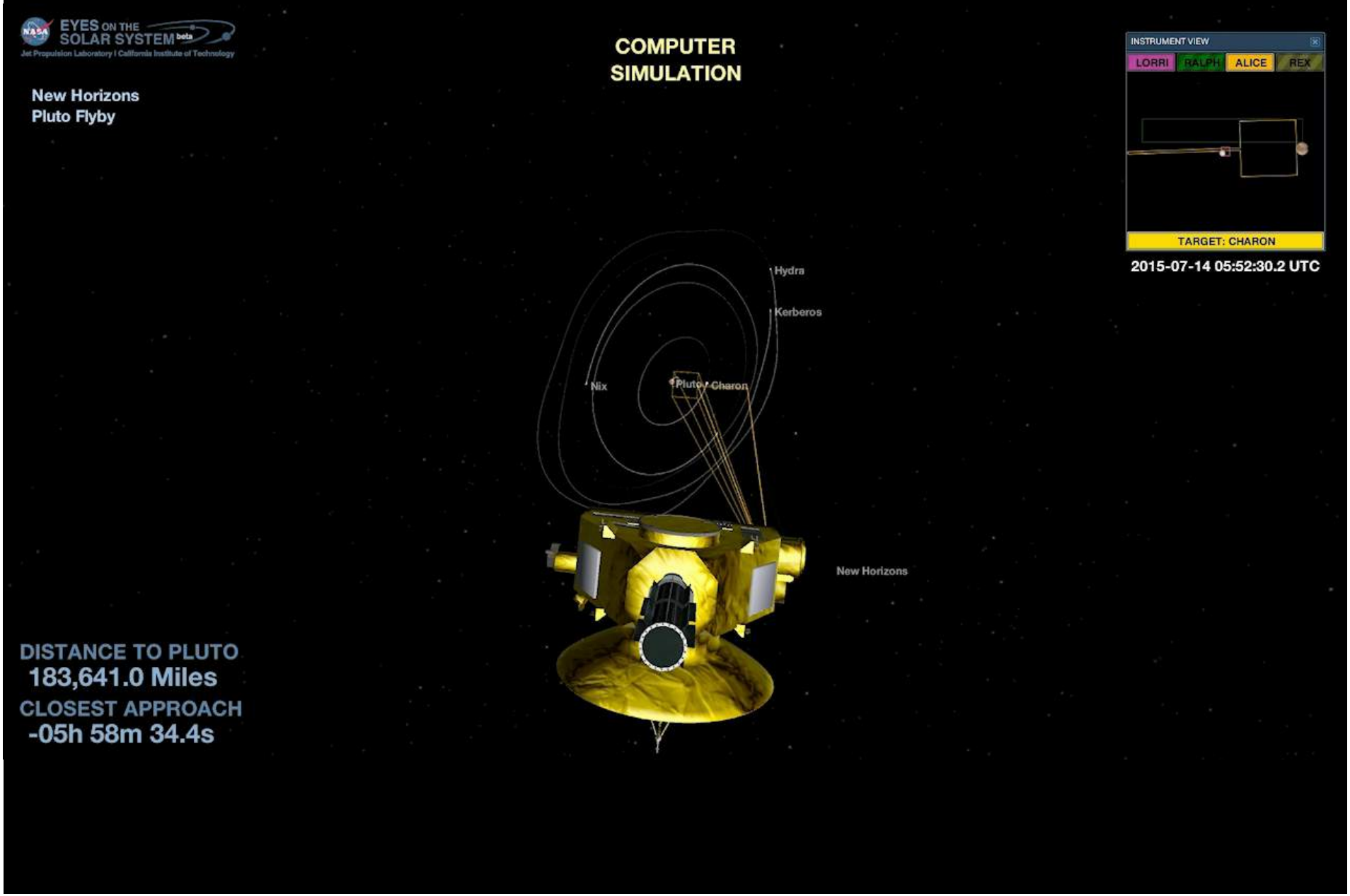
ALL PLUTO SYSTEM NAMES ARE INFORMAL AT THIS TIME

Charon and the Small Moons of Pluto



PREPROGRAMMED CHOREOGRAPHED DANCE OF OBSERVATION

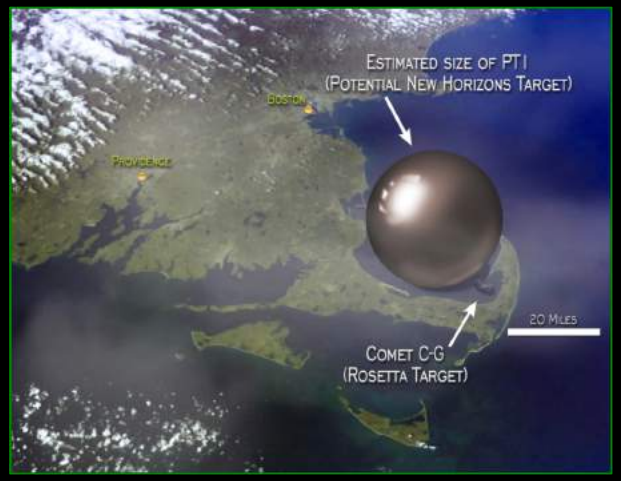
HTTP://EYES.NASA.GOV/



KUIPER EXTENDED MISSION TARGET: 2014 MU69

APPROXIMATE DIAMETER OF TARGET: 45 KM

ENCOUNTER DATE:
JAN. 1, 2019




NEW HORIZONS
2019

What We've Learned

- Prior to encounter we didn't know what to expect
- Encounter Results were not what we expected
  - Very diverse surface with what appears to be both old and new regimes
  - Evidence of dynamic processes including N_2 ice flow and convective overflow
  - Variety of surface compositions evident
  - Atmosphere with multiple haze layers
  - Etc. etc.

Some References

- The Pluto system: Initial results from its exploration by New Horizons, S. A. Stern et al., Science, 16 October 2015 vol 350, issue 6258, *aad1815*
- The atmosphere of Pluto as observed by New Horizons, G. R Gladstone et al., Science, 18 March, 2016 vol 351, issue 6279, *aad8866*
- The small satellites of Pluto as observed by New Horizons, H. A. weaver et al., Science, 18 March, 2016 vol 351, issue 6279, *aae0030*
- Pluto's interaction with its space environment: Solar wind, energetic particles and dust, F. Bagenal et al., Science, 18 March, 2016 vol 351, issue 6279, *aad9045*
- Surface compositions across Pluto and Charon, W. M Grundy et al., Science, 18 March, 2016 vol 351, issue 6279, *aad9189*
- The geology of Pluto and Charon through the eyes of New Horizons, J. M Moore et al., Science, 18 March, 2016 vol 351, issue 6279, *aad7055*